TECHNICAL REPORT
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ENGINEERING EVALUATION OF AGE LIFE EXTENSION, T-10 HARNESSES, RISERS AND T-10 TROOP CHEST RESERVE PARACHUTE CANOPIES

by

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UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

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Details of illustrations in
this document may be better
studied on microfiche

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March 1972

U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts

FOREWORD

The engineering evaluation was initiated at the request of USA AVSCOM, St. Louis, Missouri and is a continuation of a search for reliable data on which to base a justification for extending the age life of various components of troop type parachute assemblies, specifically the harness, risers and reserve parachute canopy. In the past the age life limitation was not based on reliable scientific or engineering data and was arrived at mostly by experiences based on observations by individual users with some outside assistance by technical personnel from the various services and industry, the results of which were inconclusive. Although this present evaluation more nearly brings a reasonable set of results, it is still considered necessary that a continuous effort should be made for further surveillance of these items especially if periodical turn-overs in stock are made.

The engineering and scientific evaluation presented represents a joint effort by the US Army Natick Laboratories units utilizing the scientific and engineering disciplines available at these Laboratories required for this project.

The Airdrop Engineering Laboratory (ADEL) under the direction of Colonel Donald L. Gellnicht was responsible for the initiation and direction of the overall program and the end item engineering tests. The textile engineering portion of this evaluation was conducted by the Clothing and Personal Life Support Equipment Laboratory (C&PLSEL) under the direction of Dr. Stephen J. Kennedy.

The ADEL engineering support was provided by SFC Robert L. Miller who conducted the parachute riggers inspections in conjunction with the project officer and assisted in the selection of the items to be subjected to full laboratory examination. The ADEL shock testing was conducted by Mr. H. Antkowiak under the direction of the ADEL project officer.

The textile laboratory personnel of C&PLSEL under supervision and participation of Mr. Harry Smith conducted the textile engineering phases of this evaluation. For their untiring efforts and technological expertise Mr. Michael Mahar and Mrs. Rosemary Scott are also recognized.

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ABSTRACT

A textile and engineering evaluation was conducted by the U. S. Army Natick Laboratories on T-10 troop type parachute Harnesses, Risers and Chest Reserve Parachute Canopies, obtained from world wide samplings of 6 to 10-year age classes. Despite strength losses in the nylon harness webbing and riser and the nylon canopy materials, sufficient residual strength remains in the various components to justify extension of service life above the 10-year limitation now empirically imposed on the items. An additional period of 3 years of age life appears to be justified for harnesses and risers and an additional age life of 2 years for the T-10 reserve parachute canopy. These conclusions are based on results of shock tests, laboratory data and comparison of results recorded during airdrop tests of the items at high altitude drop zones conducted by TECOM. It is considered that with prudent surveillance of the ten-year items during the additional use period the age life of harness and risers could possibly be extended an additional 2 years to a total of 15 years.

ENGINEERING EVALUATION
of
AGE LIFE EXTENSION, T-10 HARNESSES, RISERS
and
T-10 TROOP CHEST RESERVE PARACHUTE CANOPIES

I. PROJECT BACKGROUND and REFERENCES

1. Project Background – These Laboratories were verbally advised by USAAVSCOM that age life extension is required for T-10 Troop Back Personnel Harnesses and Risers on a world-wide or at least CONUS-wide basis. Consequently, a planning meeting was held at these Laboratories attended by personnel from the Airdrop Engineering Laboratory (ADEL) and Clothing and Personal Life Support Equipment Laboratory (C&PLSEL) which formulated a plan of action to acquire meaningful engineering and laboratory data on which to base a decision whether or not to extend the age life of the harness and risers. Further advisements from USAAVSCOM and concurrence by NLABS suggested that the T-10 Troop Chest Reserve Parachute Canopy be included in this evaluation. As a result of the planning meeting it was decided by ADEL and C&PLSEL to submit to CG, USAAVSCOM a proposal to determine the feasibility of extending the age life, now held at 10 years, for the T-10 Troop Type Harness and Risers and in addition for the T-10 Troop Chest Reserve Parachute Canopy. During this action on submission of the proposal, the following events occurred:

a. The proposal to evaluate the harnesses and risers (Ref 2.a.) which included sampling and funding plans was submitted. This proposal was forwarded to CG, USAAVSCOM, ATTN: AMSAV-D-L, by these Laboratories on 22 February 1971.

b. These Laboratories received the requests from USAAVSCOM to determine the feasibility of extending age life on T-10 Harnesses and Risers and the T-10 Reserve Parachute Canopies on 27 July 1971 (Ref 2.b. and 2.c.).

c. Intra-Army Order for Reimbursable Work or Services (DA Form 2544) dated 19 July 1971 in the amount of $42,740.00 was reviewed at these Laboratories on 23 July 1971 and accepted by NLABS Deputy Scientific Director for Engineering on 28 July 1971 (Ref 2.d.).

d. A transfer of funds was made to C&PLSEL in the amount of $27,000.00 by ADEL, D/F to Chief, Program and Budget on 16 August 1971 and approved.

e. The first increment of test items was received at these Laboratories from Fort Benning, Georgia on 7 September 1971 followed by an increment from Fort Bragg, North Carolina on 24 September 1971. The Yuma Proving Ground shipment arrived on 19 October 1971 followed by the USARAL shipment on 26 October 1971. The Panama

shipment was received on 6 December 1971 and the Southeast Asia shipment on 16 December 1971. No test items were forthcoming from USAEUR and it was subsequently decided after consultation with USAAVSCOM that no additional significant data could be gained by additional delays; therefore it was considered advisable to complete the report with the data compiled to date.

2. **References**

a. Letter, AMXRE-APE, dated 22 February 1971, to CG, USAAVSCOM, ATTN: AMSAV–D–L, Subject: Evaluation of Age Life of T-10 Troop Back Personnel Parachute Harness and Risers.

b. Letter from CG, USAAVSCOM, AMSAV-D-L, dated 27 July 1971, Subject: T-10 Harnesses and Risers for Age Life Extension Tests.

c. Letter from USAAVSCOM, AMSAV-D-L, dated 27 July 1971, Subject: T-10 Reserve Parachute Age Life Extension Tests.

d. Intra-Army Order for Reimbursable Work or Services (DH Form 2544) from USAAVSCOM, Order No. AMSAV-MEI No. I, dated 19 July 1971, and one inclosure.

e. Strength Losses in Nylon Parachute Materials with Time, Exposure and Use, U.S. Army Natick Laboratories Technical Report 68-45CM – March 1968.

f. Actual Extent of Useful Life of Parachute Canopy, Part II, U.S. Naval Parachuet Facility Technical Report 2-63.

g. RDTE Project No. 1F162203D 19517, USA TECOM Project No. EG-065-000-002/003, Engineering and Service Test of Standard Air Delivery Equipment (Personnel and Cargo at High Drop Zone Elevations) dated March 1971.

h. Performance of and Design Criteria for Deployable Aerodynamic Decelerations, AST-TR-61-579 (Parachute Handbook) December 1963.

II. TECHNICAL BACKGROUND

Age life limits for parachutes and accessories were established in recognition that the textile materials (predominantly nylon) are subject to losses in strength properties as a result of incidental photo-chemical, chemical and mechanical influences, as well as of degradation processes solely due to ageing. There was a pervading concept that the latter processes would generally dominate in a rather uniform manner, and hence that the time factor would be a valid as well as convenient basis for a system of reliability control. Since definitive data were not available, age limits were established and subsequently revised on practical experience and judgment, weighed by recognition that some degree of turnover of materiel was constructive in the interests of upgrading and of source viability.

Another common concept was that "nylon" was a specific and uniform material, and that the effects of age and incidental influences would follow a rather common pattern which could be represented by small samplings from any segment of the total population. For lack of feasible means for non-destructive testing of parachute items routinely on site and for lack of any consistent and adequately funded program for survey and laboratory evaluations, the age life limits have had to remain largely as a matter of judgment with little data to either support or challenge their validity. The refinements have been only in the application of jump number and repair cost factors in the formula for troop main parachutes, and (by the Air Force and the Navy) in formulas differentiating between time in initial storage and time from beginning of service.

These repair cost limitations for personnel parachute canopies are tabulated below:

Age Group Years	Months	Maximum No. of Jumps	Maximum Allowable Repairs (Percentage of Replacement Cost)
Under 4	0 to 48	40	65
4 to 7	48 to 84	70	35
7 to 9	84 to 108	90	15
9 to 10	108 to 120	100	5

The age life, also referred to as service life in Army technical manuals, for an item of airdrop equipment is specified in the joint manual TM 10-1670-201-25/TO 13C-1-41, "Maintenance of Parachutes and Other Airdrop Equipment, General." The service life of parachute canopies, paragraph 62 a.(1) states, "The service life of all personnel parachute canopies, (excluding ejection seat parachute systems) is 10 years from the date of manufacture of the canopies or 100 jumps, whichever is attained first." Service life of personnel parachute harnesses and risers (paragraph 62 a.(4)) (excluding ejection seat type) is 10 years from date of manufacture.

Fragmentary information has been obtained over the years from limited studies by the several Services. This information has been pooled and analyzed by the materials representatives under the aegis of the Joint Technical Coordinating Committee for Aerial Delivery. As one outcome, a combined proposal was submitted in November 1967 and updated in July 1969 for a continuing surveillance and analysis program thought to be the minimum which would be adequate to deal with service life and related storage and maintenance questions. Though approved in principal, the program has not been implemented. Meanwhile, NLABS had opportunity to evaluate a number of emergency parachutes of mature and near-mature age classes during the course of a trial of proposed conversion to cargo use. Insights gained from this study served to support the newer concepts of the service life problem which had begun to form under the analysis of the prior data. These were expressed in the NLABS Technical Report 68-45-CM dated March 1968, entitled "Strength Losses in Nylon Parachute Materials with Time, Exposure and Use," which had technical concurrence of the three Services' representatives (Ref 2.e).

The general import of the conclusions was that the original concepts required modifications to reflect that:

a. Ageing processes per se were not clearly evidenced as pervading factors within the 8 – 11 year time frames of the study, though Navy (NARF) studies showed indications that older age classes may show such evidences (Ref 2.f).

b. Nylon components varied considerably in strength losses according to form, supplier, color and even lot; as well as to the particular circumstances of storage and/or service.

c. Strength loss patterns determined from controlled comparison where known, or by comparison to specification or typical original values, indicated that the major effect of elapsed time is in cumulative exposures to adverse influences such as UV exposure, chemicals (including atmospheric pollution, perspiration, accidental spills), heat, over-strain, etc. These patterns showed increasing occurrence of appreciably affected items or components, and greater severity of the effects in the extreme cases, rather than a general trend or effect on the population in entirety.

d. That findings and conclusions valid to equipment of one period of manufacture may not be valid for subsequent age groups since both the susceptibilities of the materials and the types and severities of the exposures may vary widely. (A major and timely consideration is that the so-called "light and heat-resistant" nylon yarns which incorporate more effective stabilizing and inhibiting chemical additives, began to be used in some parachute components in 1963, and became generally the basis for end-item production in the course of the next four years.)

It was generally taken from the studies that the service life limitations by age were still needed as means of reliability control, for lack of predictive inspection and/or on-site non-destructive test criteria. Also, it was taken that the 10-year limitation for personnel

parachutes and accessories was not grossly inappropriate, but that a moderate extension beyond that limit might be tolerated with prudence if there were more extensive data on which to make such judgment.

The survey reported herein was made in recognition of the above premises, and was designed for the minimum sampling and testing which would be valid guidance for recommendations as to the length of extension (if any) which could be made without impairment of performance reliability under the anticipated conditions of use. The samplings included equipment from two classes approaching maturity as well as from the current 10 year class, in order to help determine trends or progression of the degradation processes and hence provide a basis for prediction and decision somewhat beyond the immediate problem with the current mature class.

III. EVALUATION PLAN and SAMPLING RESPONSE

1. Evaluation Plan

The evaluation plan was based on the world-wide test item quantities listed in the NLABS proposal. However, changes dependent upon physical appearance and available quantities were considered since it was recognized that all units in the field are not normally supplied in accordance with a specified date of manufacture of the item, and in addition parachute assemblies and components thereof may have been taken out of service through wear incurred during normal use. Each location was requested to furnish the following:

a. Twelve (12) T-10 Harnesses and Risers manufactured in 1961.
b. Six (6) T-10 Harnesses and Risers manufactured in 1963.
c. Six (6) T-10 Harnesses and Risers manufactured in 1965.
d. Twelve (12) T-10 Reserve Parachutes manufactured in 1961.
e. Six (6) T-10 Reserve Parachutes manufactured in 1963.
f. Six (6) T-10 Reserve Parachutes manufactured in 1965.

2. Sampling Response

It became apparent that the various locations solicited by USAAVSCOM could not meet these requirements. Items of 1961 manufacture were not available in some instances in the full quantities requested; therefore certain adjustments in date of manufacture and quantity were allowed. Test items actually received at NLABS for evaluation are listed below by location:

	Date of Manufacture	Number
a. Southeast Asia		
(1) T-10 Harness	1961	1
	1963	6
	1965	4

	Date of Manufacture	Number
a. Southeast Asia (Cont'd)		
(2) T-10 Risers	1959	1
	1961	9
	1963	10
	1965	10
(3) T-10 Reserve	1963	3
b. Fort Benning		
(1) T-10 Harness	1961	13
	1963	6
	1965	6
(2) T-10 Risers	1961	7
	1963	2
	1965	8
(3) T-10 Reserve	1961	12
	1962	1
	1963	6
	1964	1
	1965	1
	1966	2
c. Alaska		
(1) T-10 Harness	1964	6
	1965	6
(2) T-10 Risers	1964	10
	1965	12
(3) T-10 Reserve	1962	12
	1963	3
	1964	3
	1965	6
d. Panama Canal Zone		
(1) T-10 Harness	1961	8
	1962	1
	1963	4
	1965	3
(2) T-10 Risers	1959	2
	1960	3
	1961	3
	1963	4
	1965	2
(3) T-10 Reserve	1962	12
	1963	6
	1965	6

		Date of Manufacture	Number
e.	Yuma Proving Ground		
	(1) T-10 Harness	1961	3
		1963	2
	(2) T-10 Risers	1961	6
		1963	4
	(3) T-10 Reserve	1963	6
f.	Fort Bragg		
	(1) T-10 Reserve	1961	11
		1962	1
		1963	6
		1964	1
		1966	2
		1967	3

No harnesses or risers were requested from Fort Bragg NC. since these items from this location were previously evaluated by these Laboratories. Data obtained during the previous evaluation are included in the tabulation. The evaluation plan consisted of specific detailed actions.

a. On arrival of any increment of the required items a joint ADEL, C&PSEL Action was taken in the order outlined below:

(1) Inventory and serialize all equipment
(2) Conduct a parachute rigger type inspection
(3) Jointly select (ADEL & C&PLSEL) the items considered to be of value when exploited in a full textile engineering evaluation
(4) Jointly select items to be subjected to shock testing by ADEL

b. On completion of the above actions, the following procedures were carried out:

(1) Consolidation and evaluation of the results of textile engineering evaluation and the PED engineering evaluation. ADEL & C&PLSEL closely coordinated the final report.
(2) Based on findings of final Laboratory effort, make recommendations as to possible extension of 10 year service life limitations on the items in question.

IV. SHOCK LOAD TESTS ON RISERS AND HARNESSES

Instrumented static drop tests were conducted on jointly selected harnesses and risers. It is pointed out that all items were inspected and classified as serviceable prior to these tests. The method of testing utilized a crane to provide sufficient height. Instrumentation consisted of a Direct Record Oscillograph with a strain gauge transducer to provide a means of measuring the shock loads applied to the harnesses and risers. (Photos 1-5). The actual shock loads imposed on the selected harnesses and risers and test results are tabulated below.

The shock test loadings imposed on the harnesses and risers most significant to the evaluation are in the load range of a high of 6,200 lbs. on impact peak. Occasional low readings in the 3,800 lbs. range were recorded where outside interference occurred wherein the weight component (250 lbs. torso dummy) tumbled and became wrapped in the webbing and did not exert the full impact on the load cell.

All harnesses and risers which were subjected to the shock tests were reinspected after the tests. No significant damage was found on any of the units which could be considered a possible causative factor in the injury of personnel or catastrophic failure of harness and risers under service use. All tested units were considered to be serviceable for continued use for their intended purpose.

It is pointed out that actual drop tests conducted at high altitude drop zone elevations (10,000 ft above MSL, Ref 2.g, Chart 24) indicate that underthe worst load conditions, in essence the maximum shock loading, a full assembly, consisting of the components tested, is subjected to a considerable lesser shock load than that which was imposed on the various items during this engineering evaluation.

The following tables show the results of the shock tests conducted by ADEL. The full harness and riser configurations were shock tested in each instance. Harness tabulations were made with the objective of obtaining the most meaningful results on the shock loading on the complete harness with specific emphasis on the reaction of the shock load on the textile components. Effects on hardware was not specifically tested; however observations indicated that no adverse effects were experienced on the hardware. The same general procedure was followed for the risers and the same objectives were gained.

TABULATION OF SHOCK TEST RESULTS
T-10 HARNESS

Items Furnished from Fort Bragg, N.C.

Ident. No.	Recorded Load	Remarks
NL 1	5000 lbs.	No visible damage.
NL 3	5000 lbs.	No visible damage.
NL 4	4900 lbs.	No visible damage.
NL 5	5000 lbs.	No visible damage.
NL 7	4800 lbs.	No visible damage.
NL 8	4500 lbs.	No visible damage.
NL 9	5040 lbs.	Severe tumbling of dummy. Two broken stitches in saddle.
NL 10	2500 lbs.	Recalibration of load cell.
	2500 lbs.	Recalibration of load cell.
	4740 lbs.	No visible damage.
NL 11	6000 lbs.	No visible damage.
NL 13	5000 lbs.	No visible damage.

Ident. No.	Recorded Load	Remarks
NL 14	5500 lbs.	No visible damage.
NL 15	5000 lbs.	No visible damage.
NL 17	4500 lbs.	Riser tangled in Quick Release Box. Three stitches broken in saddle.
NL 18	5000 lbs.	No visible damage.
NL 19	5340 lbs.	Three stitches broken in saddle.
NL 20	5520 lbs.	Heavy rebound. Stitch break in saddle.
NL 21	4700 lbs.	No visible damage.
NL 23	6000 lbs.	No visible damage.
NL 25	4350 lbs.	No visible damage. Harness selected for fatigue tests.

Two harnesses selected for fatigue tests, Ident. No. NL 22 and NL 25. Twelve drops were made with each harness at a projected shock load of 5000 lbs. ± 200 lbs. Results were recorded as follows:

NL 22	Drops No. 1-6	No visible damage.
	Drops No. 7	Slight stitch damage in saddle.
	Drops No. 8-12	No additional damage except an increase of stitch damage from ¼ in. to 1½ in.
NL 25	Drops No. 1-9	No visible damage.
	Drop No. 10	Stitch break in saddle approx. ½ in.
	Drops No. 11 & 12	Slight increase in broken stitching.

Stitch breaks are attributed to hard metal surface and narrow aperture in the torso dummy and are not due to any weakness in the fabric and construction of the harness.

Items Furnished from Southeast Asia (SEA)

Ident. No.	Recorded Load	Remarks
SEA-H-63-4	4240 lbs.	No visible damage. Severe tumbling of dummy.
SEA-H-63-5	5250 lbs.	No visible damage.
	5250 lbs.	No visible damage.
SEA-H-63-6	5500 lbs.	No visible damage.
SEA-H-65-2	5000 lbs.	No visible damage.
SEA-H-65-4	3500 lbs.	Low reading due to slippage of harness main lift web.
SEA-H-65-4	6150 lbs.	Retest, 3 drops, no visible damage.
	6150 lbs.	
	6150 lbs.	

Items Furnished from U.S. Army Alaska

Ident. No.	Recorded Load	Remarks
AL-H-64-1	5400 lbs.	No visible damage.
AL-H-64-4	4950 lbs.	No visible damage.
AL-H-64-6	4800 lbs.	No visible damage.
AL-H-65-1	5250 lbs.	No visible damage.
AL-H-65-2	3900 lbs.	Low reading due to harness entanglement with hardware.
AL-H-65-3	4800 lbs.	No visible damage.

Items Furnished from Panama Canal Zone

Ident. No.	Recorded Load	Remarks
CZ-H-61-3	4800 lbs.	No visible damage.
CZ-H-61-4	5300 lbs	No visible damage.
CZ-H-61-8	4800 lbs.	No visible damage.
CZ-H-61-5	3800 lbs.	Low reading due to harness entanglement with hardware.
CZ H 63-2	5150 lbs.	No visible damage.
CZ H 63 4	4800 lbs.	No visible damage.
CZ-H-65 1	4800 lbs	Slight stitch break in saddle.
CZ-H-65 3	5150 lbs.	No visible damage.

Items Furnished from Fort Benning, Ga.

Ident. No.	Recorded Load	Remarks
FBN H-61 5	4500 lbs.	No visible damage.
FBN-H-61 6	4500 lbs.	No visible damage.
FBN H 61 8	4500 lbs	No visible damage.
FBN-H-61-10	4600 lbs.	No visible damage.
FBN H-61-12	4300 lbs.	No visible damage.
FBN-H-61 11	4600 lbs.	No visible damage.
FBN H 63-2	4600 lbs.	No visible damage.
FBN H 63 4	4700 lbs.	No visible damage.
FBN H 63-6	4500 lbs.	No visible damage.
FBN H 65 1	4500 lbs.	No visible damage.
FBN-H-65-3	4000 lbs.	No visible damage.
FBN-H-65-5	4000 lbs.	No visible damage.

Items Furnished from Yuma Proving Ground, Arizona

Ident. No.	Recorded Load	Remarks
YPG H 61 2	5850 lbs.	No visible damage.
YPG-H-61-3	5600 lbs.	No visible damage.
YPG-H-63-2	5250 lbs.	No visible damage.

TABULATION OF SHOCK TEST RESULTS
T-10 RISERS

Items Furnished from Fort Bragg, N. C.

T-9	5000 lbs.	No visible damage.
	6200 lbs.	No visible damage.
T-10	5300 lbs.	No visible damage.
T-11	5800 lbs.	No visible damage.
T-12	5300 lbs.	No visible damage.
T-13	5280 lbs.	No visible damage.
T-14	5350 lbs.	No visible damage.

Note: In addition to the above testing, risers Indent Nos. T-9 and T-10 were utilized in the harness fatigue testing which included a total of 24 additional drop tests at a load range of 5000 lbs. ± 200 lbs. with no visible damage resulting.

Items Furnished from Southeast Asia

SEA-R-61-2	5850 lbs.	No visible damage.
SEA-R-61-3	5850 lbs.	No visible damage.
SEA-R-61-6	5250 lbs.	No visible damage.
SEA-R-61-7	5250 lbs.	No visible damage.
SEA-R-63-1	6200 lbs.	No visible damage.
SEA-R-63-2	6200 lbs.	No visible damage.
SEA-R-63-5	5250 lbs.	No visible damage.
SEA-R-63-6	5250 lbs.	No visible damage.
SEA-R-63-9	6150 lbs.	No visible damage.
SEA-R-63-10	6150 lbs.	No visible damage.
SEA-R-65-3	6150 lbs.	No visible damage.
SEA-R-65-4	6150 lbs.	No visible damage.
SEA-R-65-7	5000 lbs.	No visible damage.
SEA-R-65-8	5000 lbs.	No visible damage.

Items Furnished from U. S. Army, Alaska

AL-R-65-1	5400 lbs.	3 drops. No visible damage.
	4800 lbs.	
	5100 lbs.	
AL-R-65-2	5400 lbs.	3 drops. No visible damage.
	4800 lbs.	
	5100 lbs.	
AL-R-65-6	5400 lbs.	3 drops. No visible damage.
	5100 lbs.	
	4800 lbs.	
AL-R-65-8	5400 lbs.	3 drops. No visible damage.
	5100 lbs.	
	4800 lbs.	

Items Furnished from Panama Canal Zone

CZ-R-61-3	4800 lbs.	3 drops. No visible damage.
	4800 lbs.	
	4800 lbs.	
CZ-R-61-3	4800 lbs.	3 drops. No visible damage.
	4800 lbs.	
	4800 lbs.	
CZ-R-59-1	4900 lbs.	3 drops. No visible damage.
	5300 lbs.	
	5150 lbs.	
CZ-R-59-2	4900 lbs.	3 drops. No visible damage.
	5300 lbs.	
	5150 lbs.	
CZ-R-63-1	5900 lbs.	3 drops. No visible damage.
	5300 lbs.	
	5150 lbs.	
CZ-R-63-2	4900 lbs.	3 drops. No visible damage.
	5300 lbs.	
	5150 lbs.	

Items Furnished from Fort Benning, Ga.

FBN-R-61-2	4000 lbs.	No visible damage.
FBN-R-61-4	4000 lbs.	No visible damage.
FBN-R-61-6	4000 lbs.	No visible damage.
FBN-R-63-2	4000 lbs.	No visible damage.
FBN-R-65-2	4550 lbs.	No visible damage.
FBN-R-65-6	4550 lbs.	No visible damage.
FBN-R-65-4	4700 lbs.	No visible damage.
FBN-R-65-8	4700 lbs.	No visible damage.

Items Furnished from Yuma Proving Ground, Arizona

YPG-R-61-3	5820 lbs.	No visible damage.
YPG-R-61-4	5820 lbs.	No visible damage.
YPG-R-61-5	5500 lbs.	No visible damage.
YPG-R-61-6	5500 lbs.	No visible damage.
YPG-R-63-3	5250 lbs.	No visible damage.
YPG R-63-4	5250 lbs.	No visible damage.

V. Laboratory Test Methods

A. **Webbing** - All of the webbing components are Type XIII, MIL-W-4088, Webbing, Textile, Woven, Nylon. Strength tests were made under the general conditions specified therein (Method 5100 of Fed. Std. 191), with modifications as noted below to adapt the samples to the gauge and jaws of the test equipment.

1. **Risers** - It was necessary to test the top and bottom sections of the risers separately. A free end was made in each case by cutting near one joining stitch area, and this was wound and clamped in the normal manner into one of the split-drum jaws. The upper section was tested with a heavy duty separable link connector substituted for the regular connector in the remaining stitched loop, to avoid a possible hazard in testing. This connector was engaged with other jaws by a doubled piece of separate webbing. For the lower section, the separate webbing piece was doubled through the regular canopy release hardware, for engagement with the jaw.

2. **Harnesses** - The horizontal back strap section was of sufficient length to be engaged by the split-drum test jaws in the normal manner. The diagonal back strap was tested by cutting the stitching at the forward loop (which attaches to the release assembly hardware) to open it out and make a free end. The loop for the back strap adjuster was used at the other end, but for safety the adjuster hardware (which failed as low as 2300 pounds in first trials) was replaced by a heavy duty separable link connector through which the separate webbing piece was doubled for engagement with the other jaw. The leg strap was tested by cutting at the edge of the saddle to provide one free end. A separate webbing piece was doubled through the adjustable lug hardware slot for engagement with the other jaw of the tester. Since the leg strap webbing in all the initial tests pulled through the adjustable lug until the rolled stop jammed in the lug slot, the samples in later tests were started in that configuration for the sake of uniformity of conditions.

B. **Canopy Fabric** - The canopy fabric is 1.1 oz., rip-stop, Type I, MIL-C-7020, Cloth, Parachute, Nylon. This was tested in accordance with the specification requirements except that three specimens were tested per section instead of five unless the first three indicated a sub-normal condition. The methods are 5104 for strip tensile strength and elongation, and 5134 for tongue tear strengths. Method 5450 was used for air permeability.

C. **Suspension Lines** - The lines are Type III, MIL-C-5040, Cord Nylon. These were tested for strength by Method 4102 as specified. However, a modification was made for elongation to avoid the difficulty and possible hazard of trying to determine length between the gauge marks at the actual instant of break. It was found by a series of comparisons that the same elongation values were obtained if the cord was pretensioned to a two (2) pound load, and the elongation then taken as the amount of jaw separation to the point of break. The pretensioning apparently compensates for slippage of the cord around the jaw drum. Two breaks at standard speed were made for each cord tested. Adjacent lengths were retained for impact testing on the NLABS - FRL pneumatic tester at 20 ft./sec. (750% extension/sec.) and these data are also reported for some of the samples.

D. Additional Comments - All data including visual observations were recorded with an identity code for each sample unit, and by gore and section for the canopy fabric. Subsequent analysis will be made for more obscure trends and correlations to the extent this may prove informative for future guidance. However, since the primary purpose of this survey and report was to reach recommendations for immediate decisions as to the equipment populations now in question, only the raw data and more obvious implications are presented herein together with the simplest statistical estimation of probabilities and load factors.

It is recognized that the strength data on the webbing and fabric components are solely at the slow rates of extension required in the specification tests. However, previous work has shown that the values so obtained for these types of relatively uniform woven materials are comparable to values obtained under more realistic dynamic conditions, and usually slightly lower. The same is not true for the more complicated braided-sheath and core construction of the suspension line cords, as will be discussed hereinafter.

In the evaluation results presented herein, the terms and concepts of "strength loss" are, of necessity, based on the assumed original strength level of the particular material and component in question. Since direct before-and-after comparisons cannot be made, the base range is a "typical" level somewhat above the specification minimum, which experience over the years has shown to be expected for most of the new material or stitched component. This base range also relates to the higher values in the aged population, with the reservation discussed hereinafter that nylon materials occasionally show small temporary gains in test strength during initial processes of ageing. The indicated progressions of strength loss, based on the assumptions, are required for estimating a projection to future years, and in this phase the data has to be considered en masse. However, it is the extreme case probability, rather than the general trend, which is of concern in relation to safety margins, reliability and overall hazard probabilities.

VI. Laboratory Tests on Risers and Harnesses

The total data obtained from the laboratory tests of the 104 parachutes, 99 risers and 94 harnesses received in this survey program are rather voluminous. Accordingly, for purposes of reporting and for convenience of management consideration, these data are consolidated variously in bar and spot distribution charts in order to make the findings most readily apparent.

A. Risers

Chart 1 shows separately the strength values obtained in the lower and the upper segments of the risers, organized by sample source, and by year of manufacture within that source sample. The individual spots show occurences of breaks at the loads indicated, without differentiating as to the type or location of break, and thus show the limiting strength within each sample segment. The specification reference mark shows the current

minimum strength requirement for the Type XIII webbing component of the MIL-W-4088 specification. The "control" data show typical strength values for current Type XIII webbing in the same configuration. There is no way now of determining typical original values or distribution of values for the sampled items at the indicated times of manufacture.

Examination shows no marked differences between risers from the several sources, though there appear to be some grouping of low values associated with those returned from SEA. However, since neither the histories of these risers prior to their presences in SEA nor their durations of time in SEA are known, no direct significance can be attached to the SEA climatic or geographical association. There are also suggestions of a trend of lower values with age, as for instance in the bottom segments of the risers from Panama, and in the upper segments in the SEA group. The suggested trend is considered to be a real reflection of ageing processes and cumulative exposures, though the possibility that it may also reflect original values and/or fortuitous sampling cannot be ignored.

Charts 2 & 3 show the total for all risers, and also division by the three age groups without respect to source. The general trend from the 1963 to the 1961 classes is here quite evident, though the scatter and the few low values also found in the 1965 class somewhat upset the pattern. However, it can certainly be concluded that the data are consistent with the newer concept expressed under Technical Background, which is that the service life problem is one of progressive occurrence of low strength units as a result of a variety of influences and processes which do not necessarily affect all units within an age class or population.

Chart 4 shows the distribution for all riser samples, with distinction as to whether the breaks were in the webbing or by rupture of the stitching which forms the loops. Since all of the "webbing" breaks occur at the end of the stitching in the doubled area, as is characteristic of webbing splices and stitched loops in general, neither type of break represents the full strength of the free-standing webbing, but rather, the realizable strength of the item configuration. The distinction made in this chart is to see if there are indications of greater progressive strength losses in the stitching itself than in the webbing at its weakest area next to the stitching. Since stitch breaks seldom occur in new webbing assemblies, and since there appears in the data to be a tendency for grouping of stitch breaks associated with the lower strength values and older samples, it is apparent that the condition of the stitching becomes increasingly more critical as risers continue in service. This is explainable since the nylon thread is at least equal to the webbing in susceptability to sun and chemical exposures and any direct result of ageing, and also, it is particularly subject to external chafing and (probably more importantly) to high shear forces across the stitching under impact loading which progressively weakens the thread at the interface between the two layers of webbing.

Efforts to correlate appearance of the risers to strength loss proved fruitless. Some that were apparently unused or showed little wear had similar strength levels as some others showing hard usage. No significant differences in breaking strength was found

between the relatively unused and the apparently extensively used items, by groups, which would warrant consideration of visual criteria to replace or supplement age criteria as means of determining service life. However, it should be noted here that all of the riser samples had already passed a critical riggers inspection. No conclusions should be drawn that risers which had been rejected from these same age populations during previous inspections, would also have shown strength values in the same range as the samples in the survey. Any lowering of visual inspection standards based on such a faulty assumption would seriously prejudice the validity of conclusions and recommendations made hereinafter.

The population of risers represented by the samplings can be considered as a consistent whole in the sense that no useful distinctions can be made according to location or source, to original differences related to the year of manufacture, or to normal visual criteria.

The sampling includes a number of units which show considerably reduced realizable strength compared to normal original values. The distribution suggests on a rough statistical basis that 5% of the total population of risers in these age groups have realizable strength below 4100 pounds (compared to typical orignal strength of 6500+ pounds), for an indicated loss of at least 37%. A 1% probability is also indicated by the same rough estimation, for a riser having strength below 3650 pounds. In fact, three risers in the samplings had breaks below 4300 in the lower segment, and one had a break below 4700 in the upper segment.

With these evidences of progressive losses of realizable strengths in the riser population, it is again confirmed that a generally prescribed service life limit is justified. There remains the determination of the most prudent limit to be prescribed. It is obvious that no precise limit formula can ever be derived. The rationale taken here is to assume the worst-case service conditions, and the weakest riser, and determine what margin remains.

Based on instrumented test data recorded in the USATECOM ET/ST report, reference 2g, and Chart 24, opening forces of a T-10 main parachute at 11,000 feet altitude actually show a recorded total maximum opening force of 2340 pounds. This drop condition is, of course, a very remote possibility, and is extremely severe compared to the normal premeditated jump performance envelope. On the other hand, the recorded maximum load in these test jumps is not necessarily the maximum that might be reached in all cases.

Assuming a second worst-case condition of unequal distribution between risers, the Parachute Handbook, reference 2h, and Chart 25 indicates that 67% of the total force might be applied through one riser side, and this combination would show about 1600 maximum pounds per side. A force of 2200 pounds was actually recorded for one riser side in one of the 11,000 foot drops. Since only 1% probability is roughly indicated for a strength lower than 3650 pounds in a single riser leg, a safety factor (3650 x 2/1600) of at least 4.5/1 is now (at age 10 years) still maintained for the riser side, though

conceivably there might be enough unequal distribution between legs so that this factor would be compromised on an individual leg basis. No data are available for the most unequal distribution between legs of one side, but even taking the seemingly impossible chance of one leg bearing the whole load for the side, well over 2/1 is still maintained.

Attempt was made to calculate a projection of safety factor with age for the risers (and also for the other components) using the indicated trend of the means and an assumed progressive scatter. Such hypothetical projections for the risers showed a remaining "worst condition-case" safety factor of at least 3/1 at the 13th year of continued service. However, the investigators were reluctant to suggest that such projections are valid, and accordingly the assumptions and plots are not shown in this basic report. Further analysis of the data will be done for future guidance, but the conclusions drawn herein for immediate decision are taken on the very conservative side of such projections, and are based on further surveillance as these risers continue in service.

Taking the position that any margin over a minimal 1.5/1 safety factor is prudent and acceptable for the odd chance combination of worst-case conditions plus worst sample, an extension of an additional 3 years appears to be warranted. Subject to further surveillance testing to assure against an otherwise undetected catastrophic pattern of degradation, an additional 2 years for a total of 15 years service life may also be considered a reasonable projection for planning purposes.

B. Harnesses

In the laboratory test program, strength values were obtained in three sections of the assembly as noted under Test Methods. Since these sections involved differing configurations as well as differing service load conditions and possibly service exposure conditions, this multiple approach was followed as a means of locating the "worst case" or "limiting case" within the harness assembly. It was not found practical to get meaningful laboratory test strength values for each of the complicated main lift web sections which carry the major load between the riser attachments and the distributed load system of the saddle and leg strap assemblies. However, from exploratory comparisons which were made with these double-layer constructed main sections, it was concluded that their strength would be in excess of any loads that would be transmitted through the risers and hardware. The canopy release assemblies failed at loads variously over 7,000 pounds, with the webbing assembly still intact. Also, it was concluded that any gross deterioration in this section would have been from causes such as prolonged exposure or chemical attack which would probably show similar effects in adjacent sections of the harness which were more readily tested.

1. **Horizontal Backstraps** - The horizontal back strap sections could be positioned in straight-length configuration directly into the jaws of the test equipment. Accordingly, the test values represent the basic condition of the webbing itself without the variables of hardware configuration and stitching. However, there is also possibility

that the observed relatively high average breaking strength of these back sections may also reflect their having had less exposure, handling, and contamination such as from perspiration.

As shown in Chart 5, there appear to be groupings of lower strength values for the samples from Fort Benning and Fort Bragg. These lower values are believed logically to reflect high usage rather than climatic or other geographical influences. As also shown in Chart 6, there is a prevalent association of lower values with greater age, which also holds for PCZ and SEA samples. Though this over-all trend is not dramatic, it is significant in its consistency. It is assumed that such a trend underlies the data for other sections of the harness, though obscured by the scatter caused by configuration effects and possibly more severe or frequent accidental influences for these other sections.

In practical significance, the general trend presents no apparent reliability problem within the time frame being considered. The lowest test sample value of 4700 pounds and the estimated 1% probability value of around 4200, are still well above the worst condition load value indicated from the referenced ET/ST report. Combining the maximum total load recorded in use with the reserve parachutes, and the maximum percentage of total load recorded for this harness section, as 4160 x .15, gives about 625 pounds/load for a horizontal back strap component. Obviously, from this comparison, this component of the harness assembly is not likely to be the most critical in limiting performance or reliability.

2. **Diagonal Back Straps** - The data for the diagonal back straps are given by source and year in Chart 7, and in total and by year regardless of source in Chart 8. An association of lower strength with greater age is strongly indicated for the PCZ samples; but since the scatter in the remaining data shows the considerable influence by other variables, even the PCZ data may be somewhat fortuitous. One difficulty in attempting to interpret the results causatively is the occurrence of very high values which conceivably indicate unusually high original strengths somewhat above those shown for new webbing today. Other causes are also possible, however. Apparent gains in strength have been observed occasionally in earlier studies where original strength values were known. These gains have a rational explanation which is outside the scope of this report, though discussed in referenced NLABS Report No. 68-45-CM, reference 2e, and relate to the fact that some of the possible ageing processes at the molecular and crystalline structure levels which eventually lead to strength reduction, apparently act to increase strength during the earlier stages.

The referenced ET/ST report shows a worst possible combined conditions of 4160 lbs. total load x .14 distribution factor, giving about 600 pounds for the diagonal back strap section. An ample safety factor is still indicated as being maintained at 10 years even for the worst case found which had effective strength of only 3500 pounds.

3. **Leg straps** - The strength data obtained for the leg strap sections of the harness are shown by source and year in Chart 9, and by total and year in Chart 10. There are no marked differences by source. The slightly indicated trend by age is obscured by the group of low values in the 1963 age classes from Fort Benning and SEA.

The lowest single test value is 2700, with a statistically estimated value below 2400 pounds as a 1% probability. Compared to the recorded worst possible combined conditions of 4160 total load when used with the reserve parachute at high altitude, and 10% of total load in either front leg strap, a safety factor of over 5/1 is shown. However, there is a question here as to whether the 10% distribution shown in the Handbook represents the maximum when the harness is actually used in conjunction with the reserve parachute. A higher proportion might better-be assumed, such as possibly 28% as indicated for the doubled back portion above the saddle. A remaining safety factor of slightly above 2/1 is still shown.

Since this is the lowest indicated safety factor of the three sections tested, the leg strap is taken as the worst or limiting case. There appears to be a rather small margin over the "prudent" 1.5/1 safety factor as a basis for conclusions in this study. Further examination of the test condtions, however, showed that the low test values for the leg straps reflect a final configuration in which the webbing has pulled through the adjustment hardware until the rolled "stop" at the end is jammed and pinched, and that the breaks invariably occurred there. This is considered to be an unnatural configuration because under the dynamics of loading the the lateral restraints of the elastic keeper in actual drops, the webbing does not normally pull through to that extent. It is taken, then, that the lowest "effective" strength for these leg straps in actual service would be somewhat higher than shown by the data. Supplemental testing of a few representative samples with the roll end engaged in normal fashion by the elastic keeper generally confirmed this, but it was then impossible to obtain new data for the entire sampling with this configuration. It was finally concluded that since the pull-through could happen occasionally in actual service, the test data had basic validity as representing another worst case condition. However, an actual minimum safety factor significantly above 2/1 can be assumed.

In the overall consideration, it is also recognized that the position of the leg strap on the man is such that it might be particularly subject to perspiration and other possible chemical contaminants picked up while the harnesses are being worn during ground transit as well as flight. Also, this section is as subject to chafing and abrasion as is the reinforced saddle area. In that respect as well as in its function, it may be considered the most critical section in much-used harnesses.

4. **Harness Assembly** - The laboratory test data for the three sections of the harness assembly which could be accommodated to the test equipment show a fairly consistent pattern for purposes of discussion. There is no useful distinction by source, or by particular year of manufacture except for resultant age at the time of testing. Visual

criteria did not correlate sufficiently well with test values to warrant distinction by appearance. Because of the limiting factors of stitched loops, stitched area terminal effects, and hardware configurations acting variously on two of the sections subjected to test, no obvious correlation was established between sections within each harness. (This will be subject to further analysis). The evidences of progressive loss of realizable strengths within the harness population again confirm the need for service life age limitation pending development of valid and practical inspection and/or non-destructive test procedures.

With the confirmation of drop tests (see Section IV) made on the complete harnesses in which neither failures nor evident weakening or damages were found at dynamic loads 50% above the peak shown in the ET/ST report, it can be taken from the combined data that the harness population represented by the samples are still generally serviceable and have substantial reserve capability for any but the most remote combination of worst conditions and worst sample. The strength levels and regression rates shown by the laboratory test data are taken to indicate that extension of the harness service life limit by three years should still maintain a 1.5/1 safety factor even in the remote chance combination. Further surveillance might then indicate an extension of possibly an additional two years would be warranted if by then the harnesses of the current model have not been obsoleted and replaced by improved items.

VII. Laboratory Tests on Canopy Assemblies

A. **Canopy Fabric** - The tensile strength data for the chest reserve parachute canopy fabric are shown, by source and year of manufacture in Chart 11. For simplification and because of the bias lay of the fabric in the canopy, this chart shows the averages of warp and filling values for each section tested, as indicative of general strength condition. It is seen that most of the values are well above the specification minimum requirement of 42 pounds. Limited data still at hand for that period of manufacture show typical original values to have been in the 44-49 range. Accordingly, it is thought that some of the higher test values from the aged canopies may reflect the phenomenon of strength gains occurring in early phases of ageing, which has been earlier noted.

An association of lower strength with greater age is evidenced within the sample groups from three of the sources, but not within those from Alaska which showed fairly high values as a group. For the latter, however, it is to be noted that the lowest value of all was in a parachute from Alaska, which illustrates the difficulty in making any generalizations or predictions. Also, typical of the difficulty, is that the next two lowest strength canopies were from the PCZ which represents the opposite climatic extreme. Unfortunately, the full history is not known for any of these canopies.

The overall distribution of warp and filling tensile strengths is further indicated in Chart 12, with distributions by age in Chart 13. The regression tendency with age is evident, though the scatter which prevents close predictions is also apparent. The mid-range scatter of results is partly in that warp strengths tend to run a bit higher than filling

strengths, though specification minima are the same and the two are of equal significance in the bias-cut canopy. Actually, the low and high ranges of stretch values both include warp and filling data.

There are no specific formulas available for relating the complex bi-axial or radial peak force loads on canopy fabric during opening, with the unidirectional tensile strength values for the fabric as obtained in laboratory tests. Consequently, direct estimation of safety factors cannot be made from the test data as was done for the risers and harnesses. However, for guidance, reference was made to studies conducted by the Joint Parachute Test Facility at El Centro, California, as reported in their summary Technical Report No. 2-63 (reference 2f).

In the El Centro studies, parachutes of various ages and resultant strength properties were subjected to high impact drop tests at 300 KIA with 200 pound load, actuated by 15 foot static lines. Resultant damage and performance were rated. The parachutes included groups which had strength values in the same ranges as shown by those reported herein. Under this severe drop test condition, some degree of fabric damage was sustained by all but one of the 65 parachutes tested, although only one was rated as damaged to the extent as to cause probable loss of a parachutist. The comparisons showed that within this combination of fabric strength-strength ranges and opening load ranges there was no clear correlation of degree of damage with either parachute age or strength level as measured by laboratory test.

In this regard it is to be noted that canopy damage in opening of personnel parachutes in normal service usually results from a line-over, twist, snag or drag in which the forces clearly overpower even the full strength fabric, or else there are bruises or frictional "burns" from deployment such that the damaged fabric will burst or split when opened. Failure in straight force breaks or bursts is quite uncommon. In further confirmation of the relative insensitivity of the canopy strength - damage relationship within typical parachute populations is that none of the troop parachutes involved in fatality failures (each of which has been sent to NLABS for thorough examination and testing) has shown fabric strength significantly below normal or specification minimum requirements. Put another way, there is no history of sub-standard fabric strength having caused fatal failures.

Expected total opening loads on troop chest reserve parachutes in premeditated jumps or even emergency bail-outs are considerably below those in the 300 KIA static line drop tests at El Centro, noted above, for parachutes of similar area of the same 1.1 oz. rip-stop nylon. It is logically concluded that similar strength samples revealed in the present survey would not increase the frequency or extent of damage, compared to the new and normal strength canopies, when used under the expected conditions of the reserve or back-up system.

From the above it could be concluded that the canopy population represented by the samples in this survey are fully serviceable. This is stated in the sense that under either 1) the case of a normal deployment or 2) that of an abnormal deployment causing

damage, the parachutists injury or loss probability would be no greater than if the entire population of these parachutes had full fabric tensile strength. However, other tested characteristics should also be considered.

The distributions of elongation values as shown in Charts 14 & 15 are very wide. Though the proportion falling below the specification minimum of 20% is not large, well over half are below the usual 26-30% range which new fabric shows. The effect of reduced elongation of canopy fabric from older parachutes is difficult to assess. In an accelerated type of ageing test such as exposure to high heat or to solar or artificial radiation, low elongation is generally associated with low breaking strength, resulting in a double loss of work or energy to break (toughness). This pattern was not found in the tensile-elongation data obtained for canopy fabrics in this survey. A separate correlation analysis was made graphically as shown in Chart 16. The apparent lack of any consistency in the tensile strength and elongation relationship again illustrates the inability to derive simple explanations or conclusions from data representing the results of complex causes and effects in the "real time" ageing and service environment.

A tentative explanation for some of the scatter in the strength-elongation relationship is the aforementioned phenomena of ageing process which initially tend to increase rupture strength but at the expense of elongation or "yield" in the plastic region of the elongation curve. Other partial explanation lies in the artifacts of the laboratory strip tensile strength test itself which is influenced by frictional and cross-directional effects which may variously raise or lower the rupture load of the test strip and also the extension reached at the point of rupture.

Further analysis was made of the elongation characteristics in what is considered the "useful" portion of the stress-strain curve. It is to be noted in this regard that conventional elongation data represent the total extent of stretch at the occurrence of rupture, and that with normal new nylon this includes considerable plastic flow or "yield" as the material starts to fail under load. This yield region does not provide useful tensile resistance except in a very rare instance where a sudden release of load might leave the material still intact though over-strained. Accordingly, a number of comparisons were made of the load-elongation curve traces on te recorder charts from Instron tensile test machine. It was found that the shapes of the lower and middle parts of the curves were very similar for high and low elongation samples of both the high and low tensile strength materials. Also, a good part of the differences between high and low elongation patterns were in the above-mentioned yield region. At both strength levels, the lower elongation samples consistently showed slightly higher modulus or stiffness in the lower and middle regions (though without evidence of dangerous brittleness) which is what one would expect as a result of the type of ageing processes which initially raise and then lower rupture strength values.

The repeated references to this type of ageing processes are made with intent to remind the reviewer that raw data showing high strength levels on aged equipment do

not necessarily indicate that "nothing has happened" to the material since time of manufacture. They may, in contrast, actually signal that ageing processes are already underway which will eventually act to reduce basic fiber strength and/or structural strength efficiency.

Another indication of serviceability is tear strength, data for which are presented in Charts 17 & 18. With the exception of the deteriorated canopy from Alaska, all other samples met the original specification requirement of 4.5 pounds minimum, and mostly with ample margin. Since tear strengths depend even more than tensile strength on a number of variables such as internal friction, "set" of the fibers and yarns, etc., as well as the intrinsic fiber strength, detailed discussion of the complex causative factors underlying the data would be beyond the scope of this report. The most important generality is that tear strengths of canopy fabrics tend to increase somewhat over the original values as result of mechanical flexing and "working" as in inspections and packing. This results from the loosening up of cross-yarn woven grid structure so that there is a more favorable distribution of tearing type forces and hence greater resistance to initiation and propagation of tears. This effect is somewhat of a "saving grace" in that it overcomes to a considerable extent minor unfavorable changes in strength and/or elongation of the fibers themselves. Counter to this, there may also be a tendency to lower tear strength if the lubricating finish applied to the fabric in manufacture hardened or became gummy with age. Limited studies made previously on parachutes of older (pre-1965) periods of manufacture did occasionally show this tendency. However, no such effect was evident in the present survey.

The generally high tear strength pattern shown in this sampling of canopies is considered to be of major significance in terms of serviceability. As previously noted, canopy damage generally originates with a local cause (snag, burn, etc.) which either overpowers or weakens even normal fabric. However, the extent of the damage which propagates from the originating local damage will depend to considerable extent on the tear strength of the adjacent area. Data which can be interpreted as illustrating this effect are in the referred to 300 KIA drop tests made at El Centro on parachutes of various ages and strength properties. The unused, under 1 year of age parachutes had a higher portion of damage sufficient to affect safe descent than any intermediate group, and the next groups showing damage to this extent were the 9 and 10 year age classes. This is not conclusive, particularly since the actual pre-drop tear strengths of these under 1 year canopies were not known. The relatively high tear strengths shown in the report were taken after the drop, and hence represent fabric which had already been loosened. It may be assumed from other historical data, however, that the original, or before-drop strengths of the new parachutes were significantly lower, and that this condition was associated with the relatively greater extent of damage for this group in the test drop.

Air permeability data are shown in Charts 19 & 20. There are a few values outside the original specification range limits of 80 to 120 cu. ft./min. However, the pattern is quite normal and shows no marked trend though underlying the scatter is probably the usual slight rise in air permeability as the fabric is initially handled, due to the loosening

of yarns, as was mentioned in regard to tear strength. The El Centro drop test data showed no obvious correlation of extent of damage with air permeability (after dropping) through an equally wide permeability range. The changes in air permeability caused by the drop are unknown, but since they usually are increases, the levels as well as the range before dropping also would have corresponded with those shown in the current studies. There appears to be no cause for concern with regard to air permeabilities of T-10 chest reserve parachutes canopies represented in this survey.

The overall conclusion from the tensile, elongation and tear strength data from the parachutes represented, is that with the one possible exception of the one degraded unit from Alaska, the canopy fabrics are in serviceable condition. However, extension of service life will be considered also with reference to the observed condition of the suspension lines, and with respect to the significance to be given to the Alaska unit.

B. **Suspension Lines** – The breaking strength data from the standard specification test method at low extension rate are given in Chart 21 by source location and year of manufacture, and overall by year group in Chart 22. The lowest values are in the high-use Fort Benning and Fort Bragg groups, and particularly in the Fort Benning group in association with the greatest age. Over 30% of thetotal number are below the specification minimum requirement of 550 pounds, and in the 1961 class the proportion below specification is 51%. The lowest strength value found is 36% less than the minimum specification requirement of 550 pounds.

These results are quite consistent with earlier studies which show that these nylon cords are particularly sensitive to influences occurring during service according to specific circumstances, as well as to mechanical effects and possibly to general degradation based on age alone. The patterns are very similar to those in the referenced survey of 140 C-9 parachutes as shown in NLABS Technical Report 68-45-CM (Ref 2e). The observed changes and resulting scatter of results are thought to reflect, variously, (1) basic changes in the properties of the fibers and yarns which directly affect strength; (2) basic changes in fiber and yarns which indirectly affect cord strength by lowering the mechanical efficiency of the core and braided sheath structure; and (3) mechanical shifting of the sheath along the core which locally lowers the efficiency of the structure.

Supplementary analysis was made of the data differentiated according to the three manufacturers as indicated by yarn color codes. No relationship was apparent which would explain the range of results since high and low values were associated with each. The pattern of behaviour appears to be characteristic of the basic cord construction rather than being related to the several yarn variables which are allowed under the specification description.

Further studies were made of a selected number of the cord samples by impact tests at 750% extension/sec. As had been shown in earlier studies, impact strengths and elongations of suspension line cords as measured by the NLABS-FRL impact tester in general have considerably lower values than by the standard test. Correlation has always

been poor, but for rough estimation the impact value would run about 65% of the breaking strength by the standard test. This difference is in part due to lowered efficiency of the complex cord construction as extension rate and resultant fiber modulus is increased. It probably also reflects the whip action of the sample which of necessity under this test condition starts in a completely slack configuration and is brought to straightness between the jaws only with the impact force. This action somewhat simulates the movement of the suspension lines in an actual deployment, hence is a valid condition of test.

The comparisons of the data from the two types of tests made on adjacent sections of the same lines showed no clear correlation trend, and included some very marked contrasts in both directions. Part of this may be due to actual differences in basic strength along the same lines, which could very well occur due to differing exposures and contaminations, and may be due to the previously noted shifts of sheath along the core which would change the efficiency in local sections. However, since it is the immediate practical implications rather than the technical explanations which are of concern here, further discussion of causes will be deferred pending subsequent analysis.

The impact data serve to confirm that there are a number of lines in the sampling that show considerably less strength than new cord usually shows. Values as low as 270 pounds were found, compared to about 370 for new cords and about 325 for the better samples in the survey.

There are no available data for actually recorded maximum loads on individual suspension lines at any drop altitude. As a rough estimation of magnitude, however, the extreme worst total case of 4160 pounds, and maximum unequal load percentage per side of 69%, are combined and divided by 12 for the number of lines per side, to give a maximum load per line of 240 pounds. Allowing for some unbalanced load distribution, it appears that in the combination of worst possible condition and worst sample, failure of the line might be expected. In the referenced El Centro drop tests at 300 KIA, as many as three lines did actually break in a few of the units. Significantly, however, the breaking of those few lines did not affect the descent rate or success of the drops. The El Centro samples included some which showed even lower strength (standard tests) than were found in this survey. Also, of course, the 300 KIA drop condition which frequently show opening forces well over 5000 pounds are much more severe than a T-10 Chest Reserve parachute would encounter in even the most extreme case contemplated.

C. **Parachute Assemblies** – In reaching a conclusion for the parachute assemblies as a whole, it must be recognized that there is possibility that the populations now in question include some small number of units which would sustain more damage than would a "normal" parachute under equally very severe opening conditions. As witness the noted low strength 1962-3 canopies from Alaska and the PCZ, and various low strength lines, these units are not necessarily in the oldest age class within the population. There are

two questions to consider. One is as to the probabilities of the worst case combination. The other is the seriousness of the "more damage" in the eventuality of such a combination.

It is highly significant in these considerations that no parachute in this survey was found to be generally weakened in all or the majority of its parts. This observation does not deny that over-all or predominately weakened areas could occur in exceptional circumstances which violate all maintenance and care guidelines. The findings here as well as the El Centro studies do, however, typify the pattern expected from present knowledge of the external causes of severe degradation. These would most likely affect only locally exposed areas of fabric or sections of the lines, with the adjacent sections remaining quite normal. Accordingly, in considering the worst case probability for the canopy assemblies, there is one more level of chance than with harnesses and risers. This is in the combination of worst condition of local load distribution within the unit, with the worst local section or line within the unit. Though these probabilities cannot be estimated mathematically from any available data, it is obvious that the odds or chances of the three-level combination "worst case" are extremely low.

Also, though it is the intent to provide full reliability in all units continued in service status, the consideration of ultimate risk will take to account that relatively few chest reserve parachutes will ever be put to actual use. Further, even on some of these occasions, particularly in training, the success or failure of the drop will depend on factors other than the strength condition of the materials in the reserve parachute.

The second question as to the significance or seriousness of the greater canopy damage or broken lines has been discussed. In summary it can be said, from historical experience and the El Centro studies, that the drop condition envelope in which the differences or losses in material strength which were found might prove critical, is very narrow. Also, this envelope is considerably above the normal operational envelope for T-10 Troop Chest Reserve Parachutes.

Notwithstanding the above, it must also be recognized that canopy fabric and lines are more susceptible to accidental adverse influences than are the heavy webbing in risers and harnesses. Relatedly, the accuracy of any prediction of the extreme worst unit within the total population will be less. For these reasons, as well as the relatively lower safety margins, a more conservative view must be taken as to extension of service life. The conclusion for the canopy assemblies is that the extension for the age class populations represented in the survey should be limited to two years. Any extension beyond that should be contemplated only if so warranted by results of an equally extensive survey being made towards the end of the 12th year.

VIII. Summary Conclusions and Recommendation

1. **Risers** – It is concluded that T-10 Troop Parachute Riser Assemblies of 1961-1962 and 1963 years of manufacture, worldwide, are suitable for continued service through 13 years from date of manufacture indicated thereon.

2. **Harnesses** – It is concluded that T-10 Troop Parachute Harness Assemblies of 1961–1962 and 1963 years of manufacture, worldwide, are suitable for continued service through 13 years from date of manufacture indicated thereon.

3. **Canopy Assemblies** – It is concluded that T-10 Troop Chest Reserve Canopy Assemblies of 1961-1962 and 1963 years of manufacture, worldwide, are suitable for continued serviced through 12 years from date of manufacute indicated thereon.

4. **Extrapolation** – It is concluded that the deterioration processes acting on nylon parachutes and accessories are highly complex and specific to histories of the individual units and area within units. It is recommended that no extrapolation of conclusions from this survey of T-10 Troop Harnesses, Risers and Chest Reserve Parachute Assemblies be made to other types of equipment and service environment and use conditions.

5. **Surveillance** – It is recommended that a sustained program be initiated for annual review of the current populations of riser, harness and canopy assemblies, with objectives to include:

a. Consideration of further extension of service life for the age classes listed above.

b. Develop data on up-coming age classes from 1964 and onwards.

c. Reveal any changes in the general situation resulting from changes in material (e.g., introduction of light and heat resistant nylon during the 1964-1966 period), and/or changes in environment (e.g., atmospheric pollution, maintenance discipline, operating procedures, etc.)

PHOTO 1
T-10 Troop Type Parachute Harness Rigged on 250 LB Torso Dummy

a. Harness
b. Load Cell and Wiring
c. Drop Line
e. Manual Release

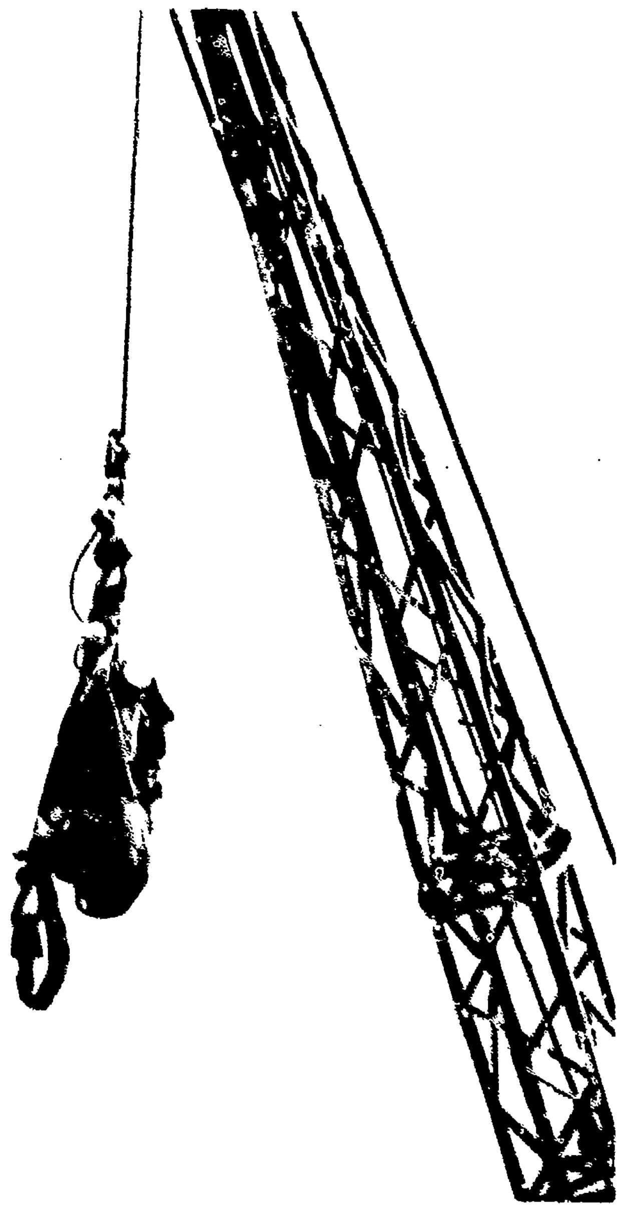


PHOTO 2
Harness and Torso Dummy Suspended Prior to Drop from Crane

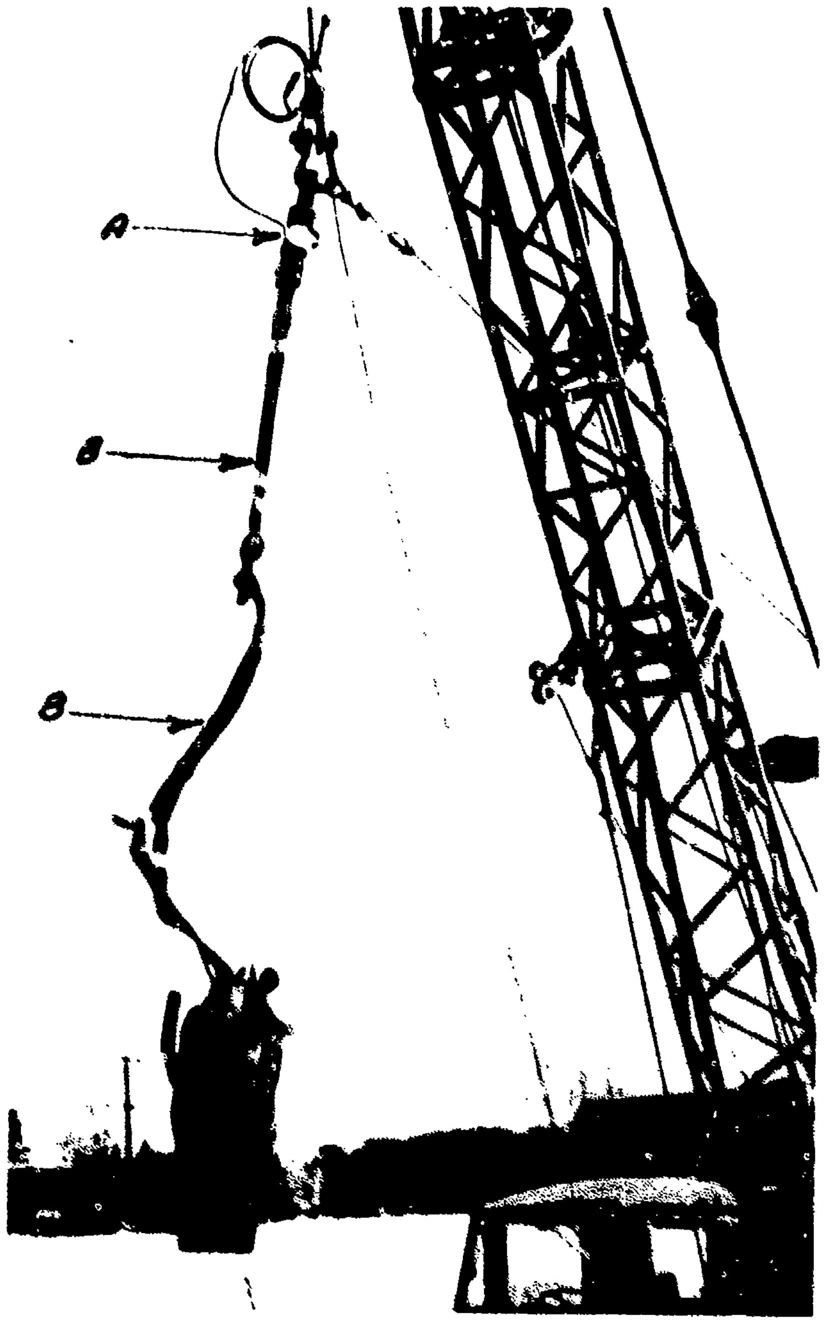


PHOTO 3

Harness and Dummy During Drop Prior to Impact

a. Load Cell

b. Drop Line

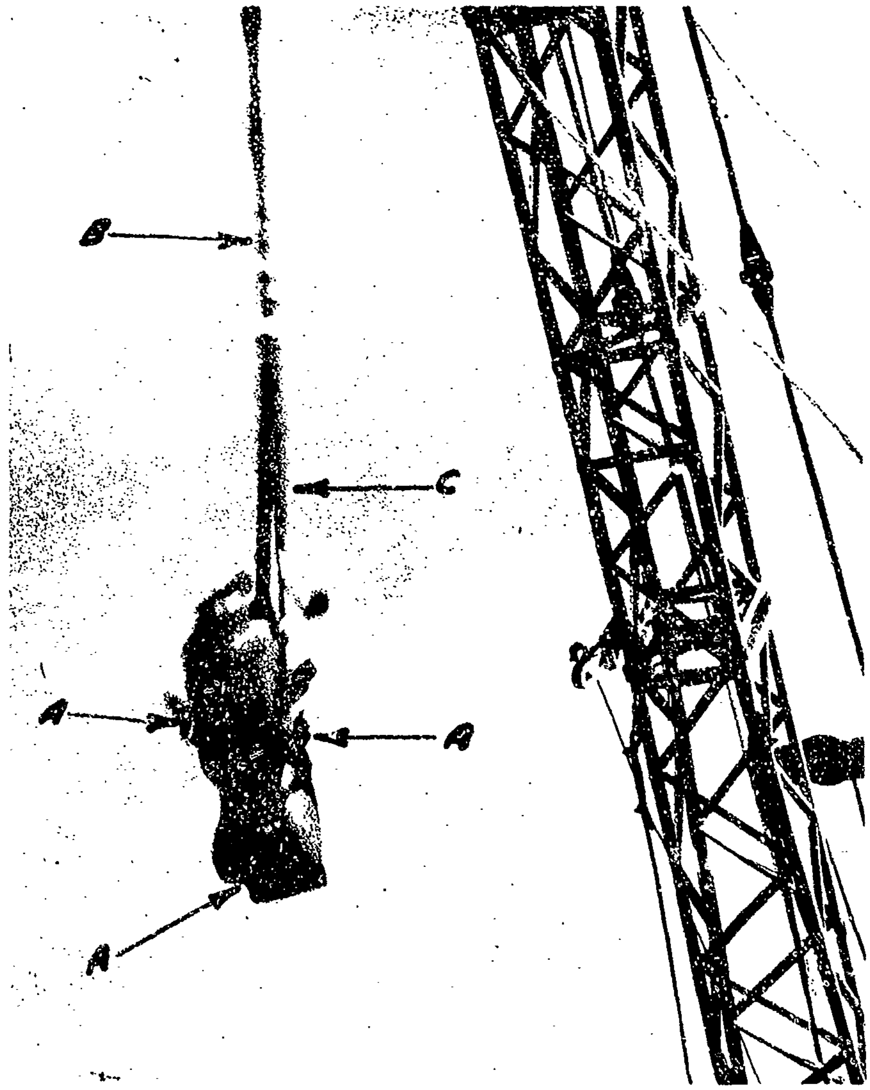


PHOTO 4
Harness and Dummy at Moment of Impact
- a. Harness
- b. Drop Line
- c. Risers

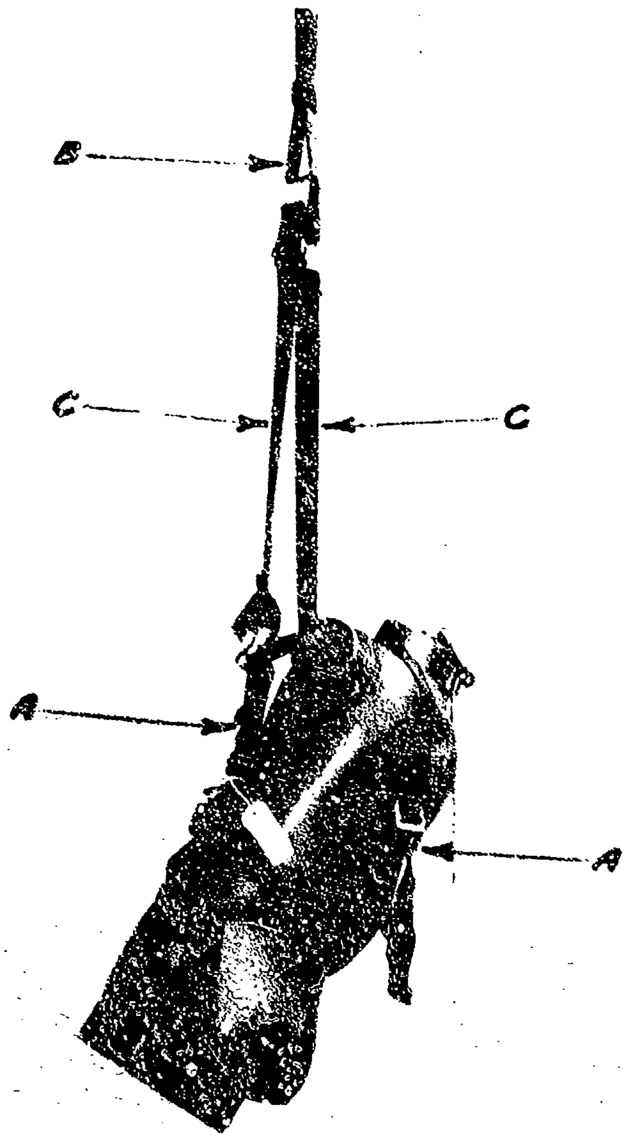
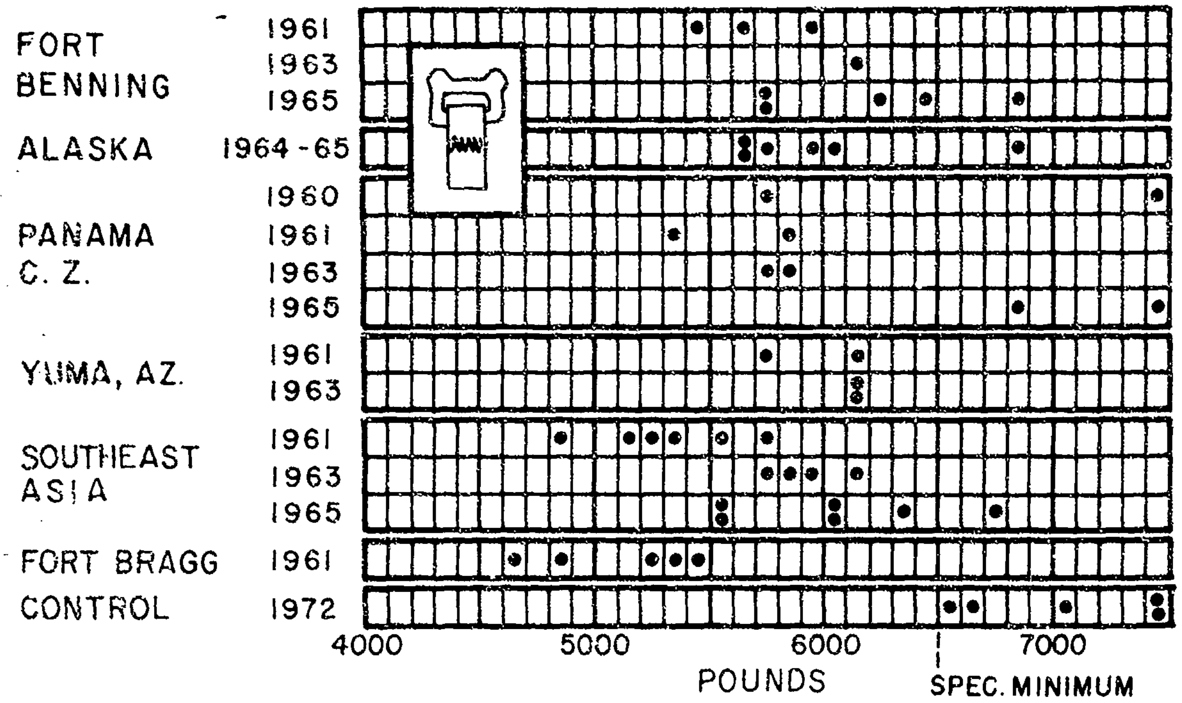


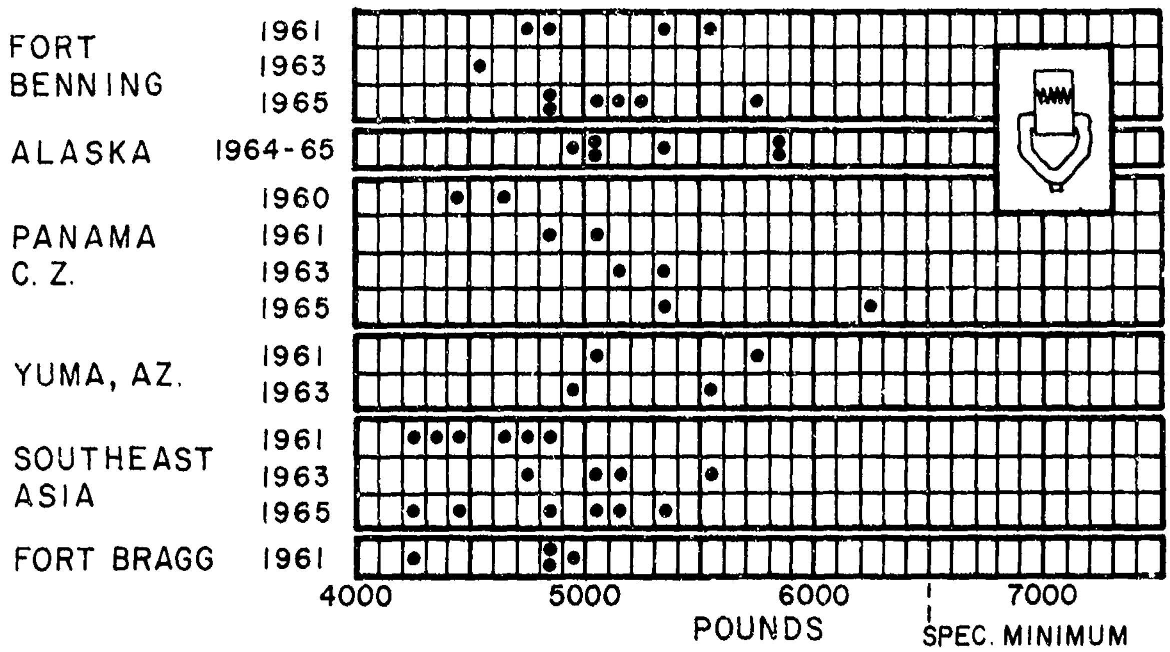
PHOTO 5

Harness and Dummy Suspended After Impact

a. Harness
b. End of Drop Line
c. Risers



UPPER END OF RISER LEG WITH SEPARABLE LINK CONNECTOR
(HEAVY DUTY)



LOWER END OF RISER LEG WITH ORIGINAL HARDWARE RETAINED

CHART 1 BREAKING STRENGTH OF RISER LEGS

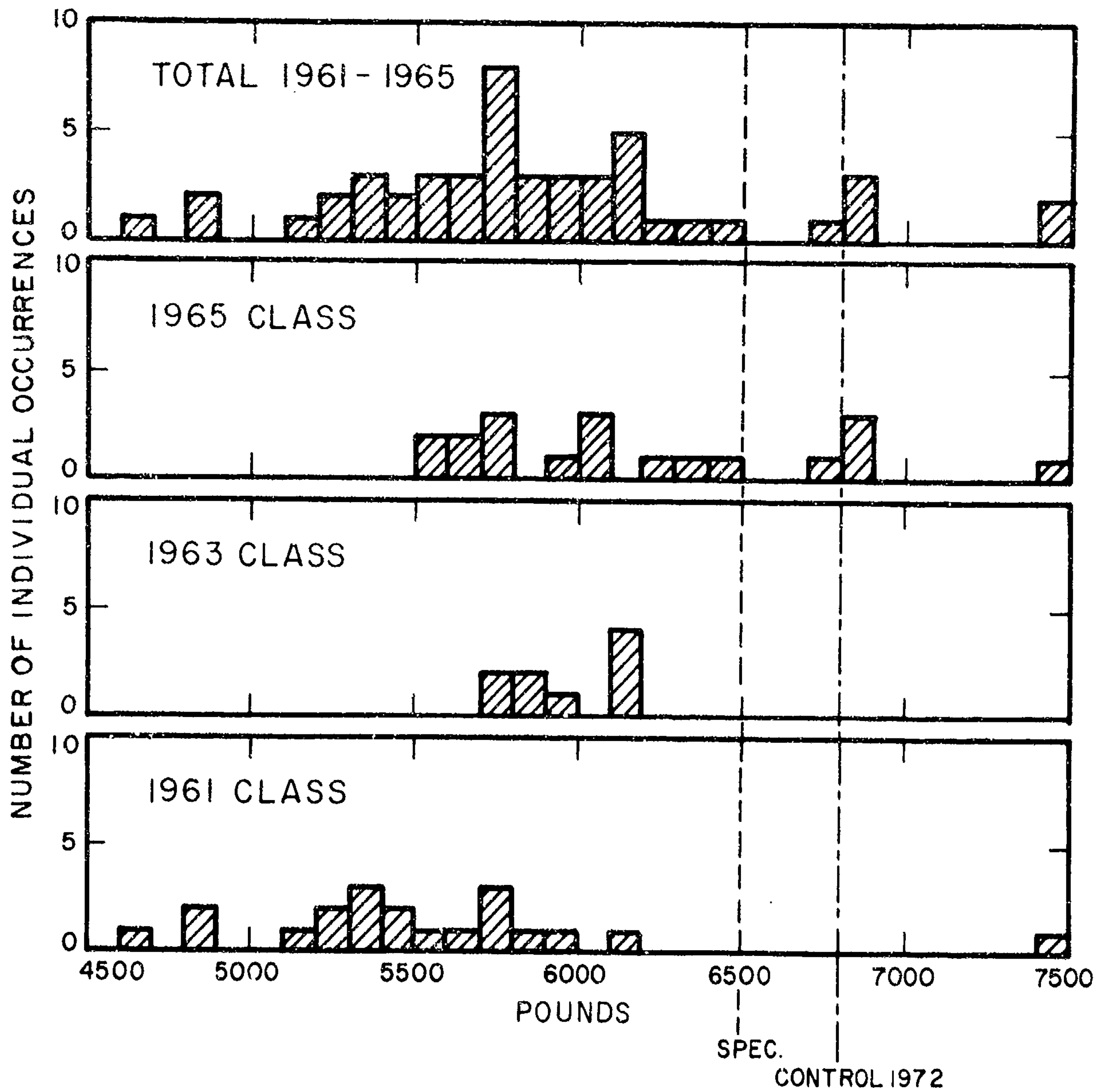


CHART 2 BREAKING STRENGTH FREQUENCY DISTRIBUTION OF RISER LEGS, UPPER END WITH SEPARABLE LINK CONNECTOR (HEAVY DUTY)

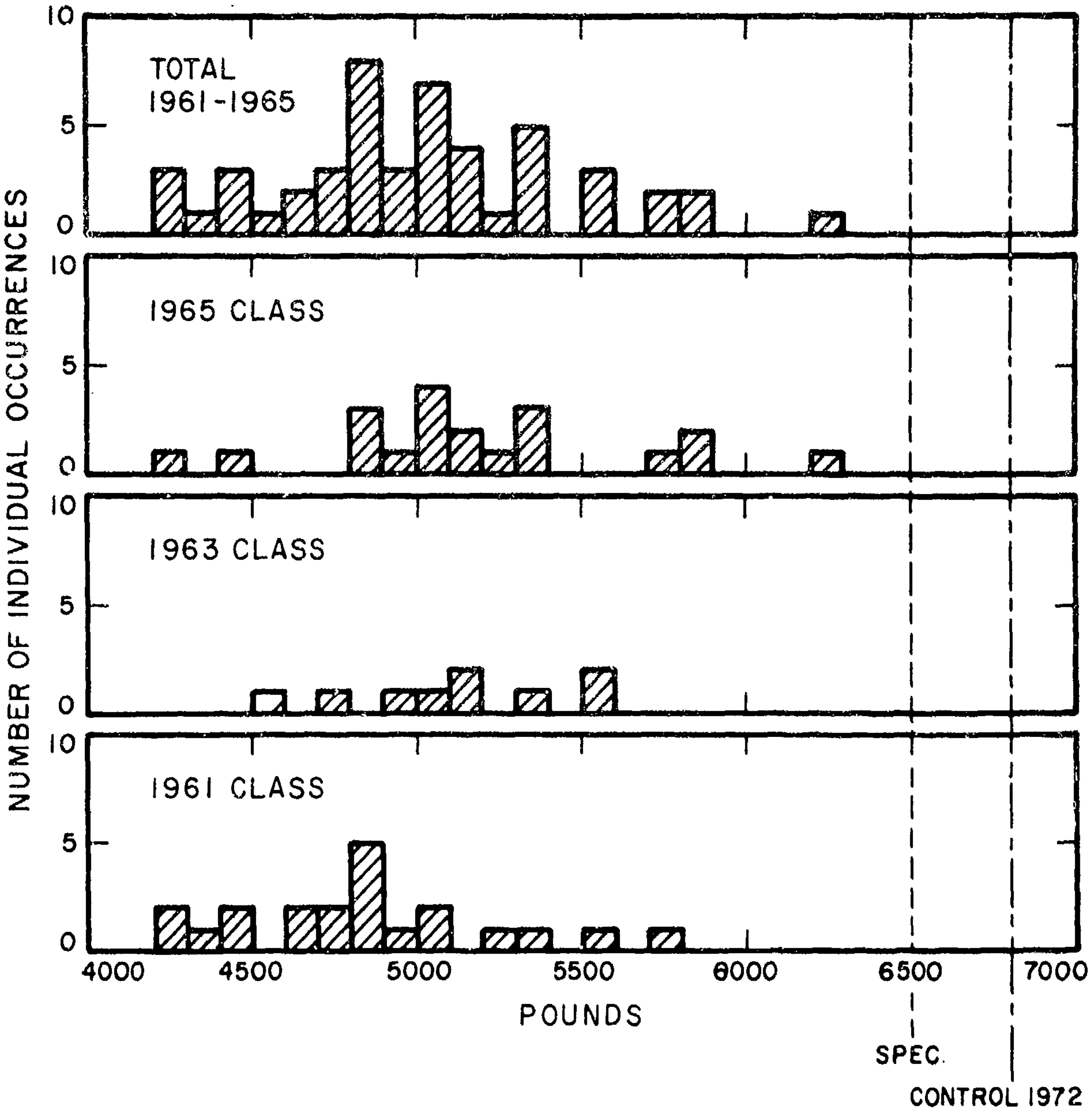


CHART 3 BREAKING STRENGTH FREQUENCY DISTRIBUTION OF RISER LEGS, LOWER END WITH ORIGINAL FITTINGS

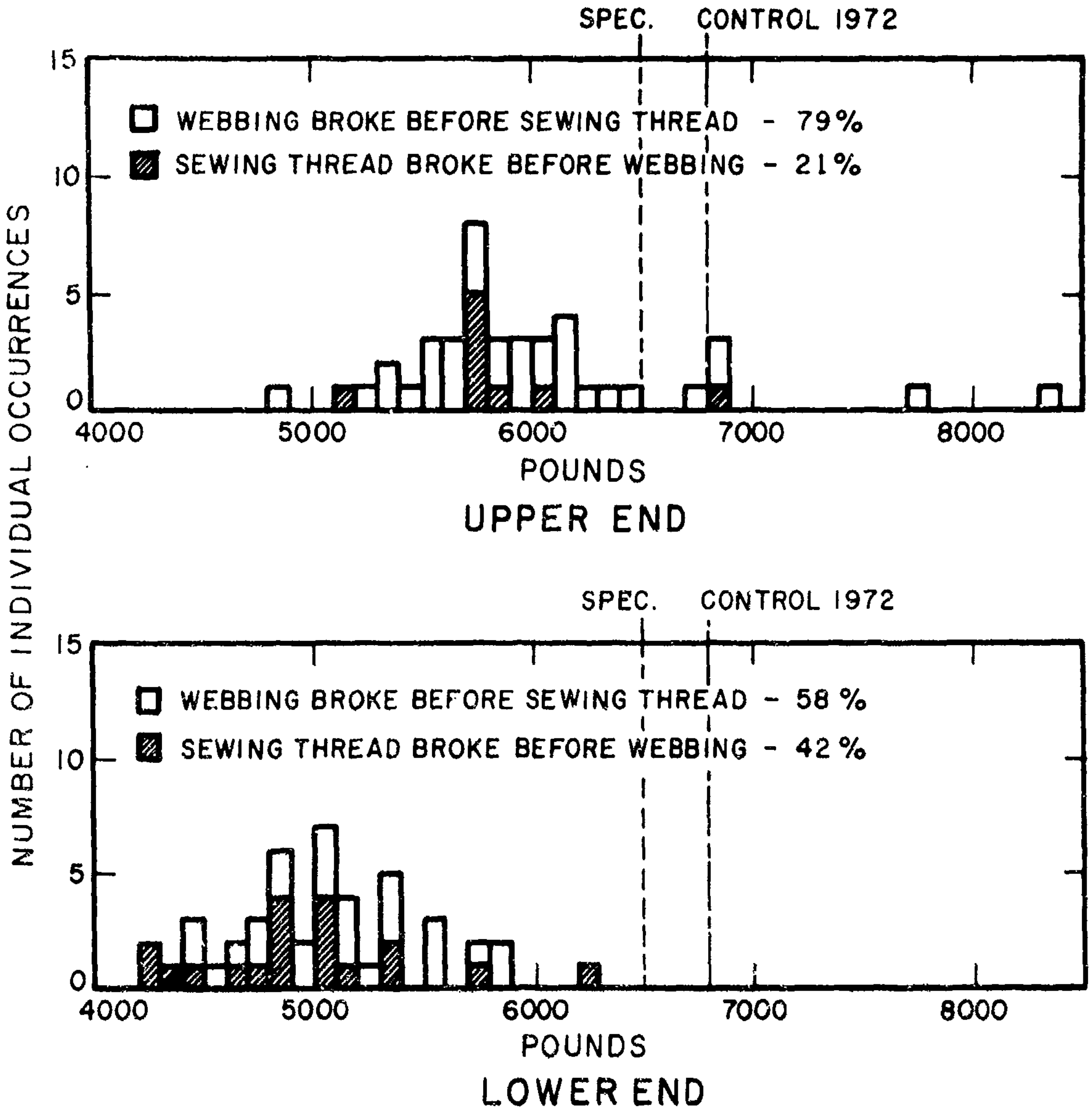


CHART 4 BREAKING STRENGTH FREQUENCY DISTRIBUTION - BY TYPE OF BREAK

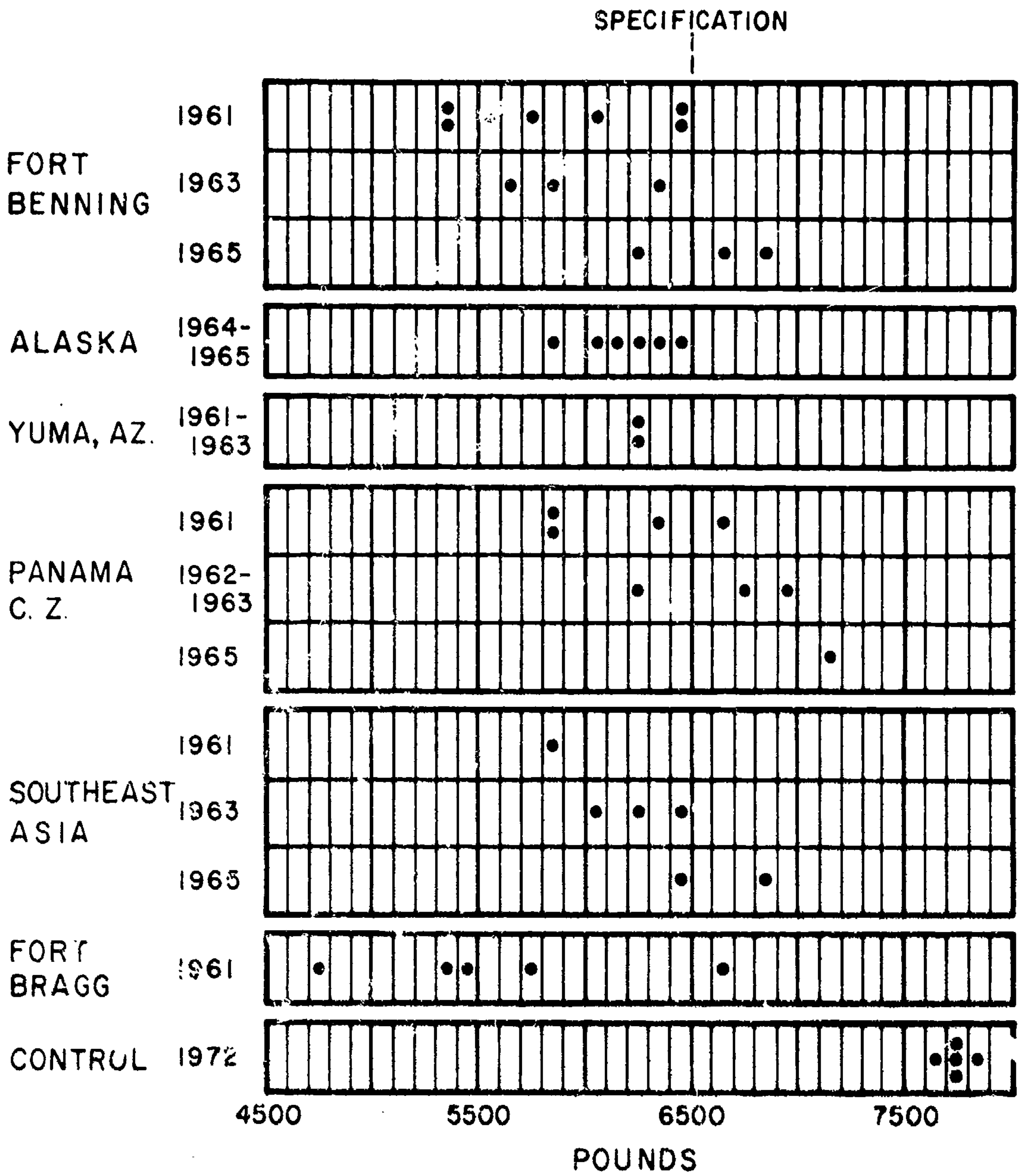


CHART 5 BREAKING STRENGTHS OF HORIZONTAL BACKSTRAPS FROM T-10 PARACHUTE HARNESSES

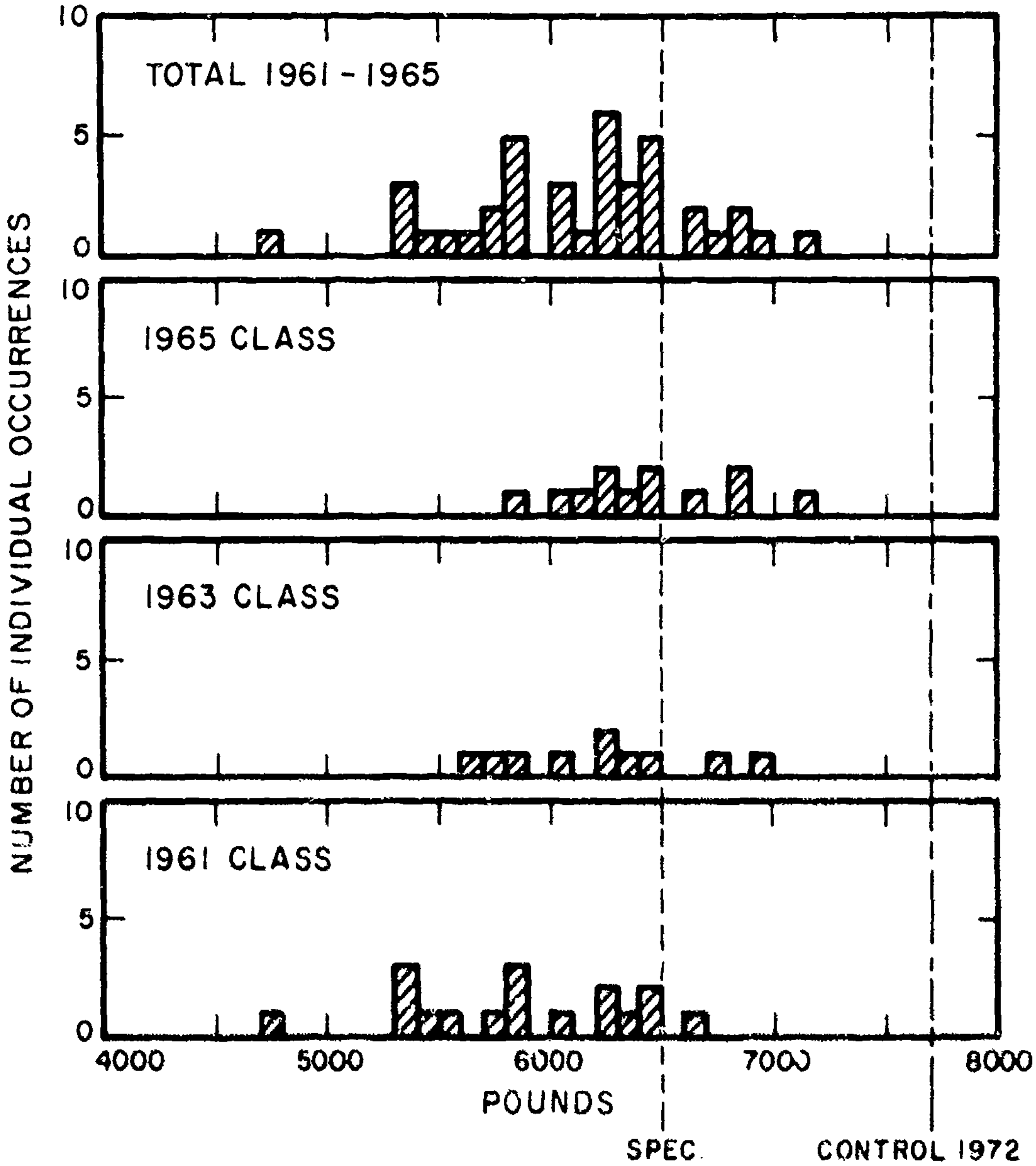


CHART 6 BREAKING STRENGTH FREQUENCY DISTRIBUTION OF HORIZONTAL BACK STRAPS FROM T-10 HARNESSES

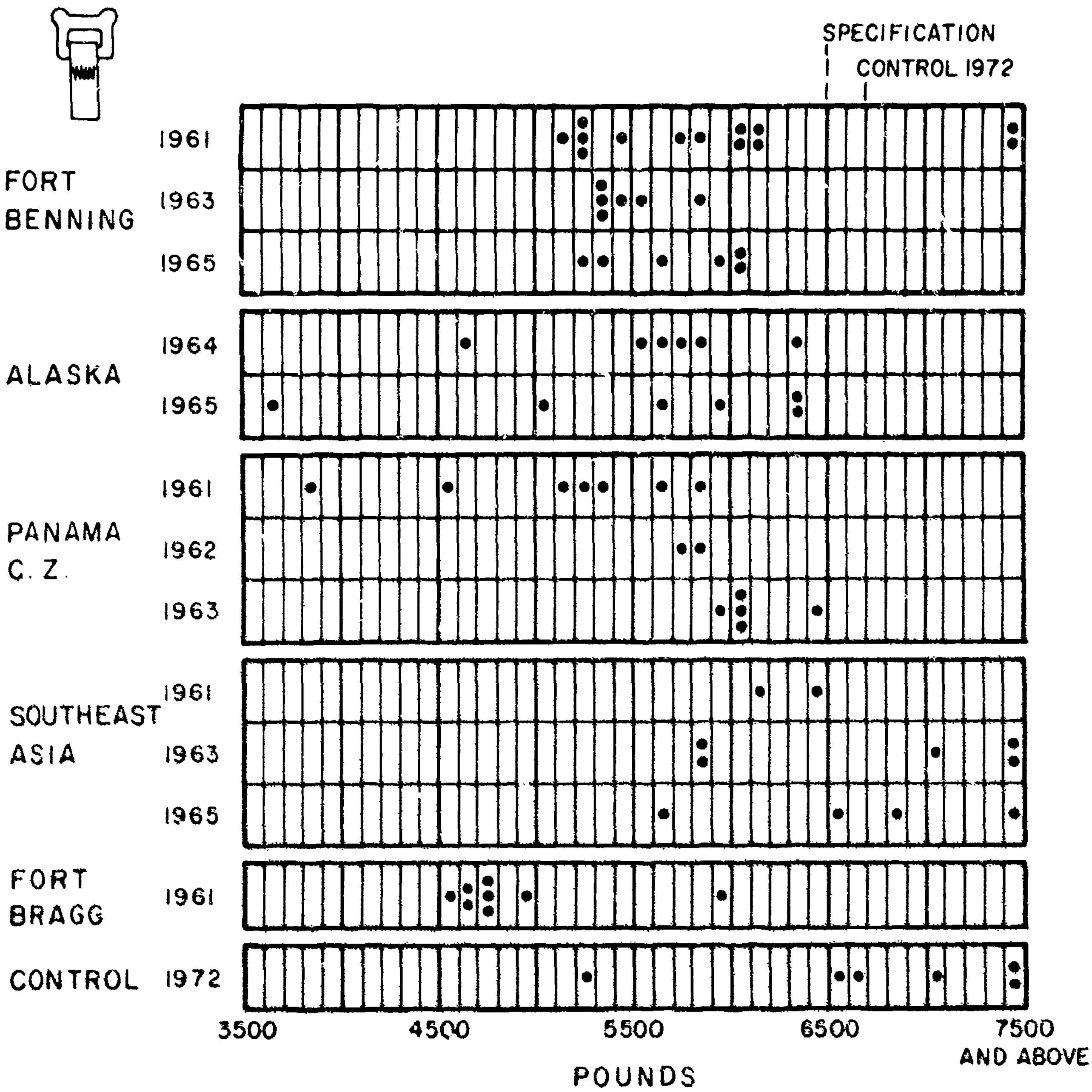


CHART 7 BREAKING STRENGTHS OF DIAGONAL BACKSTRAPS FROM T-10 HARNESSES

HARDWARE SEPARABLE LINK CONNECTOR, HEAVY DUTY

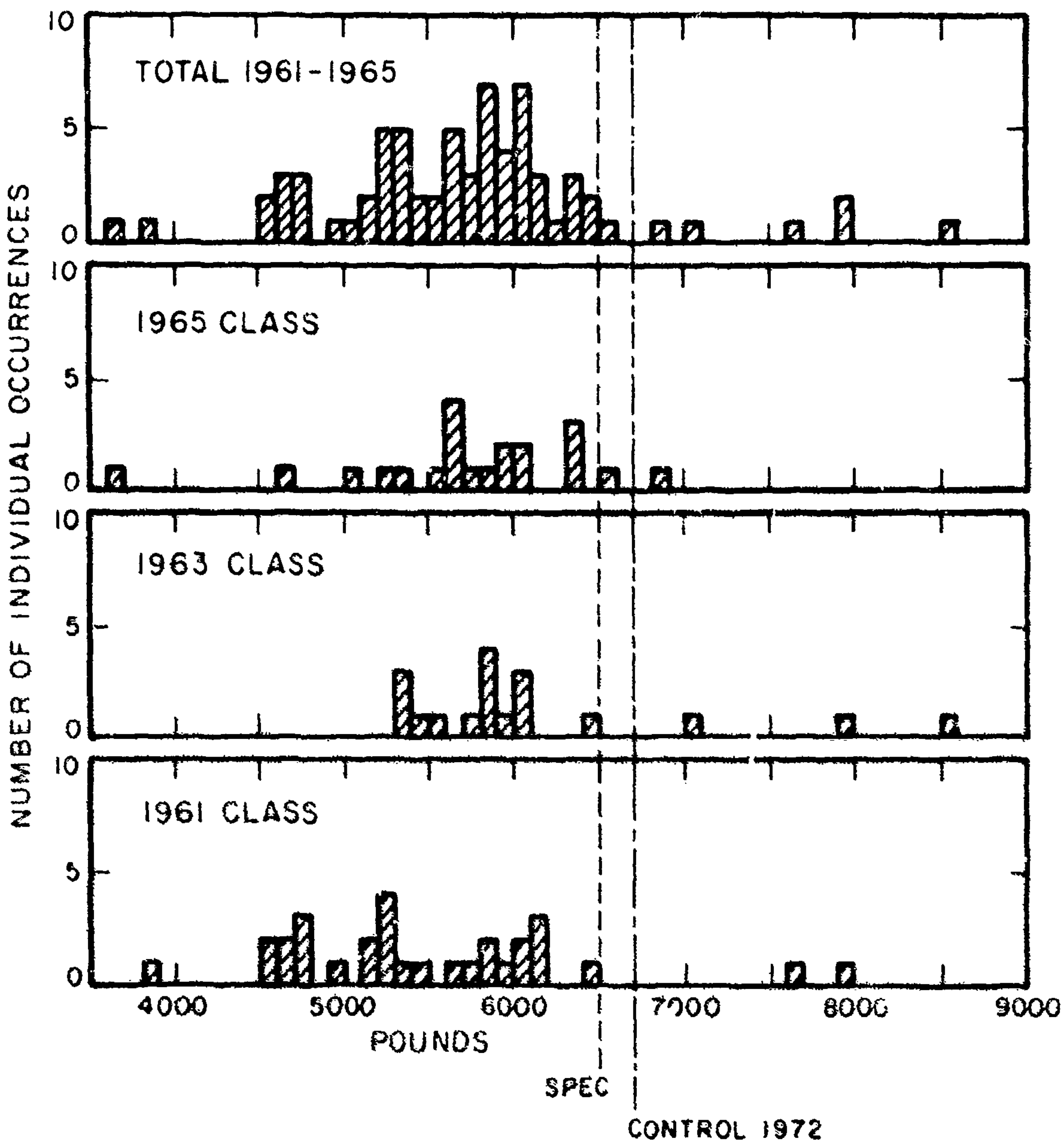


CHART 8 BREAKING STRENGTH FREQUENCY DISTRIBUTION OF DIAGONAL BACKSTRAPS FROM T-10 HARNESSES

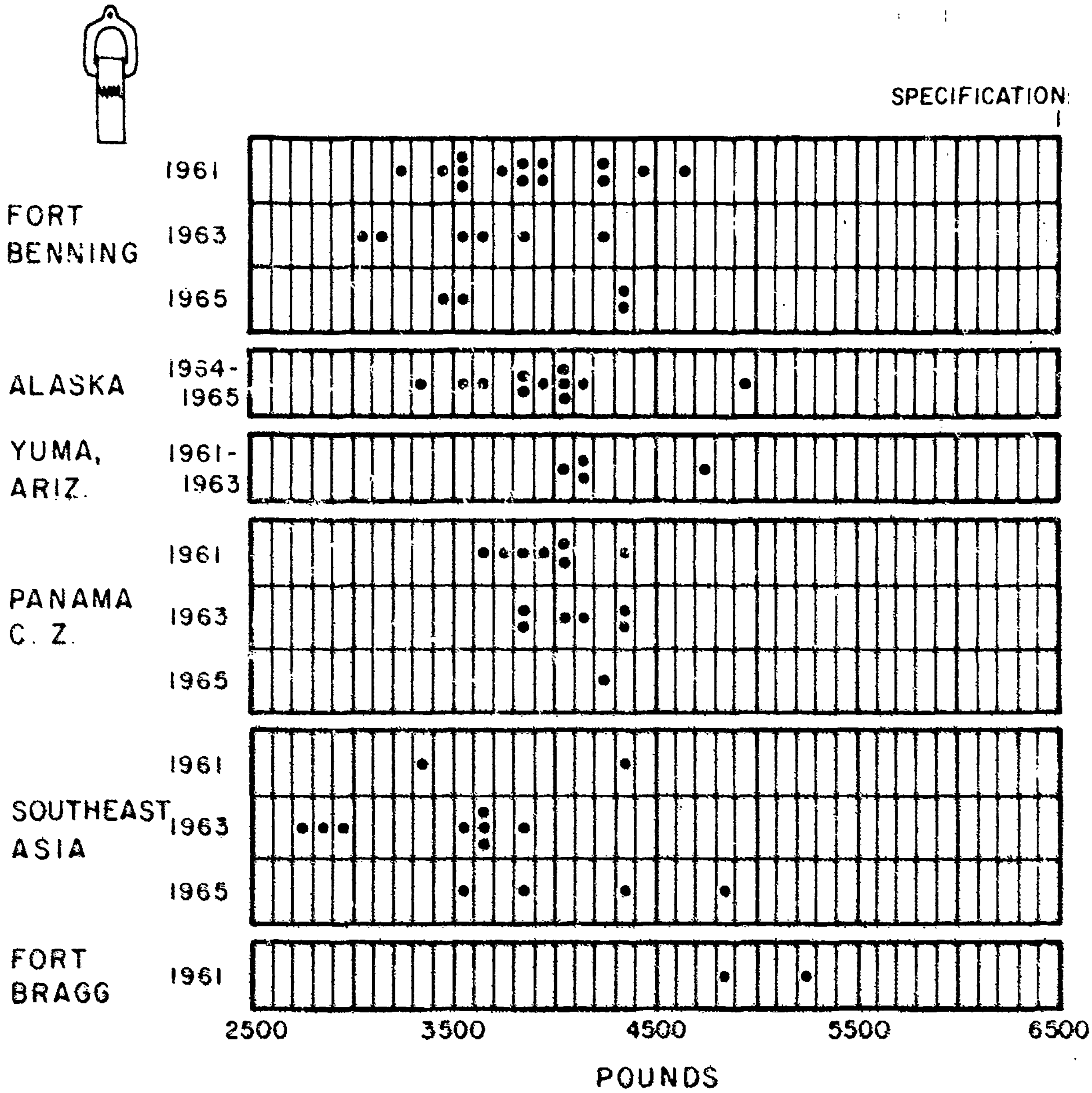


CHART 9 BREAKING STRENGTH OF LEG STRAPS FROM T-10 HARNESSES

ORIGINAL HARDWARE USED

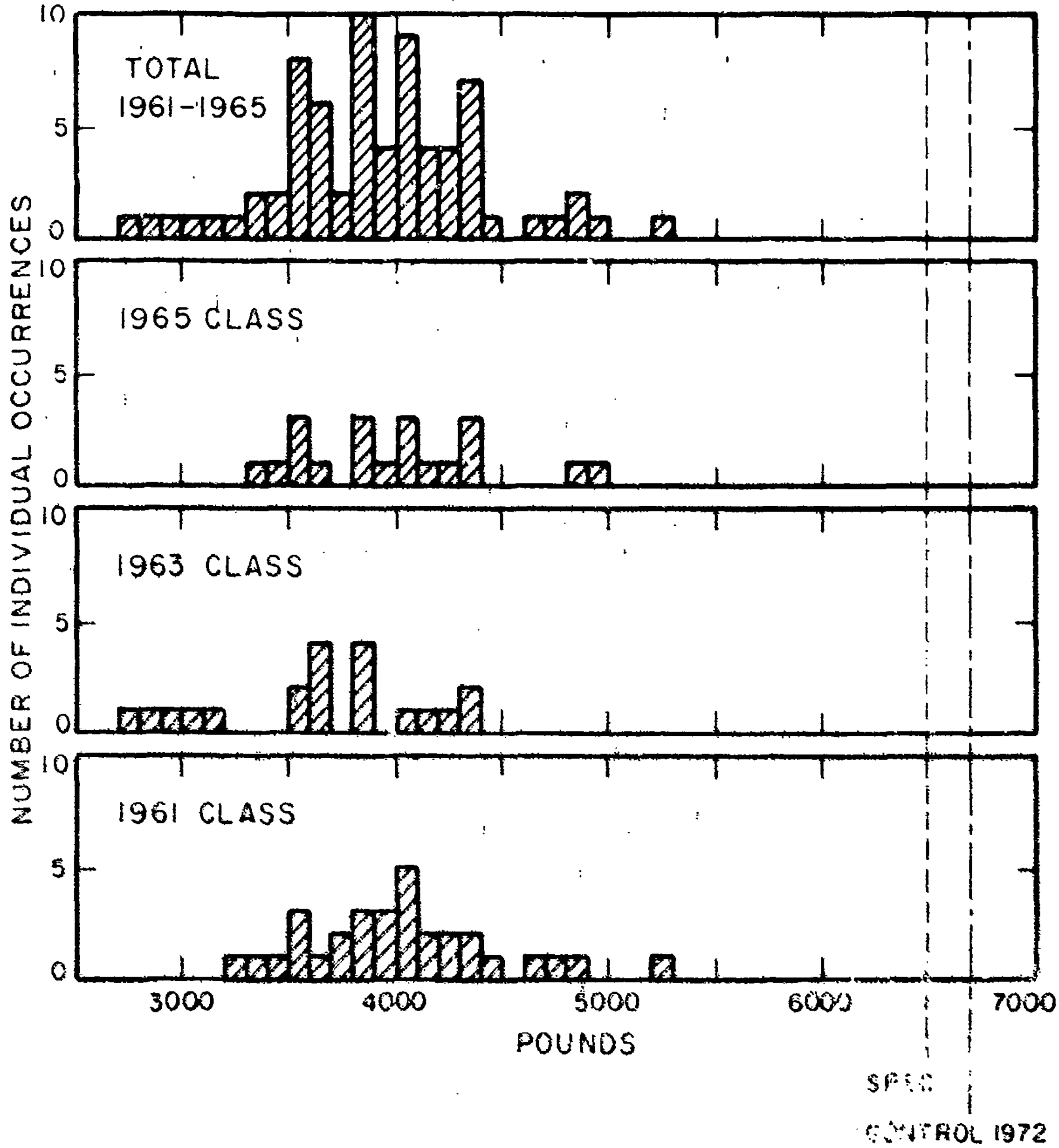


CHART 10 BREAKING STRENGTH FREQUENCY DISTRIBUTION OF LEG STRAPS FROM T-10 HARNESSES

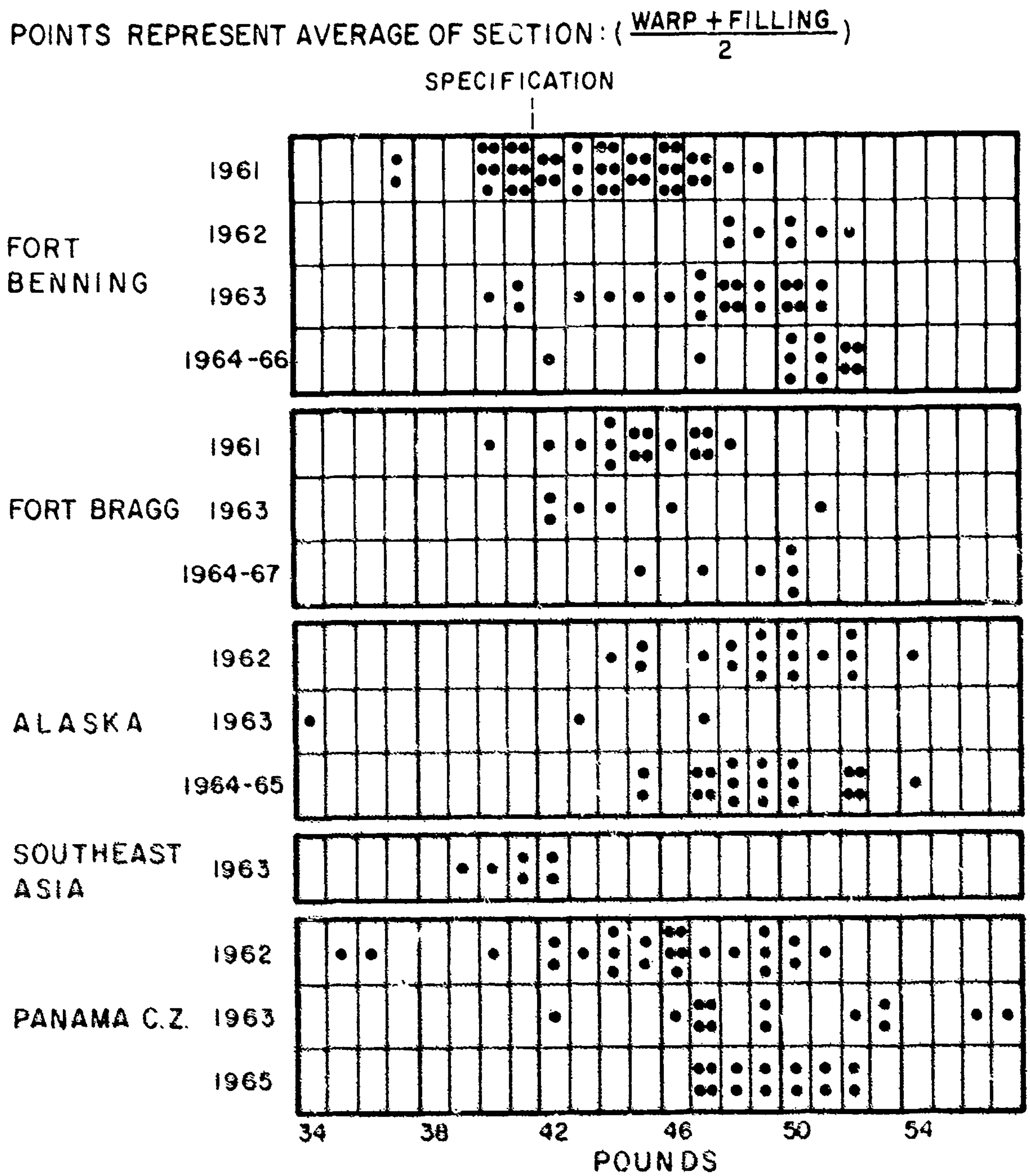


CHART II BREAKING STRENGTHS OF CANOPY FABRIC SECTIONS FOR T-10 CHEST RESERVE PARACHUTES

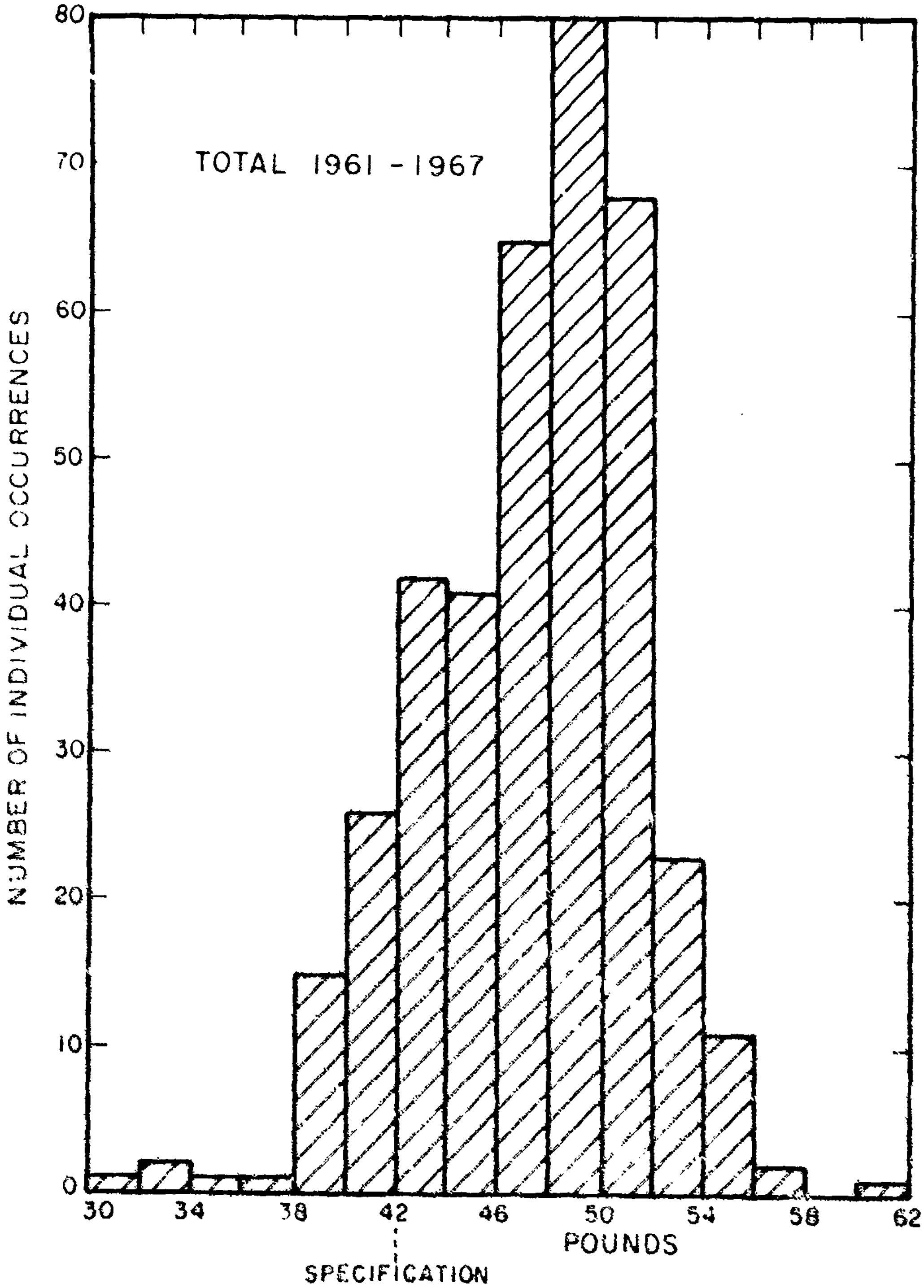


CHART 12 BREAKING STRENGTH FREQUENCY DISTRIBUTION OF CANOPY FABRIC SECTIONS FROM T-10 CHEST RESERVE PARACHUTES

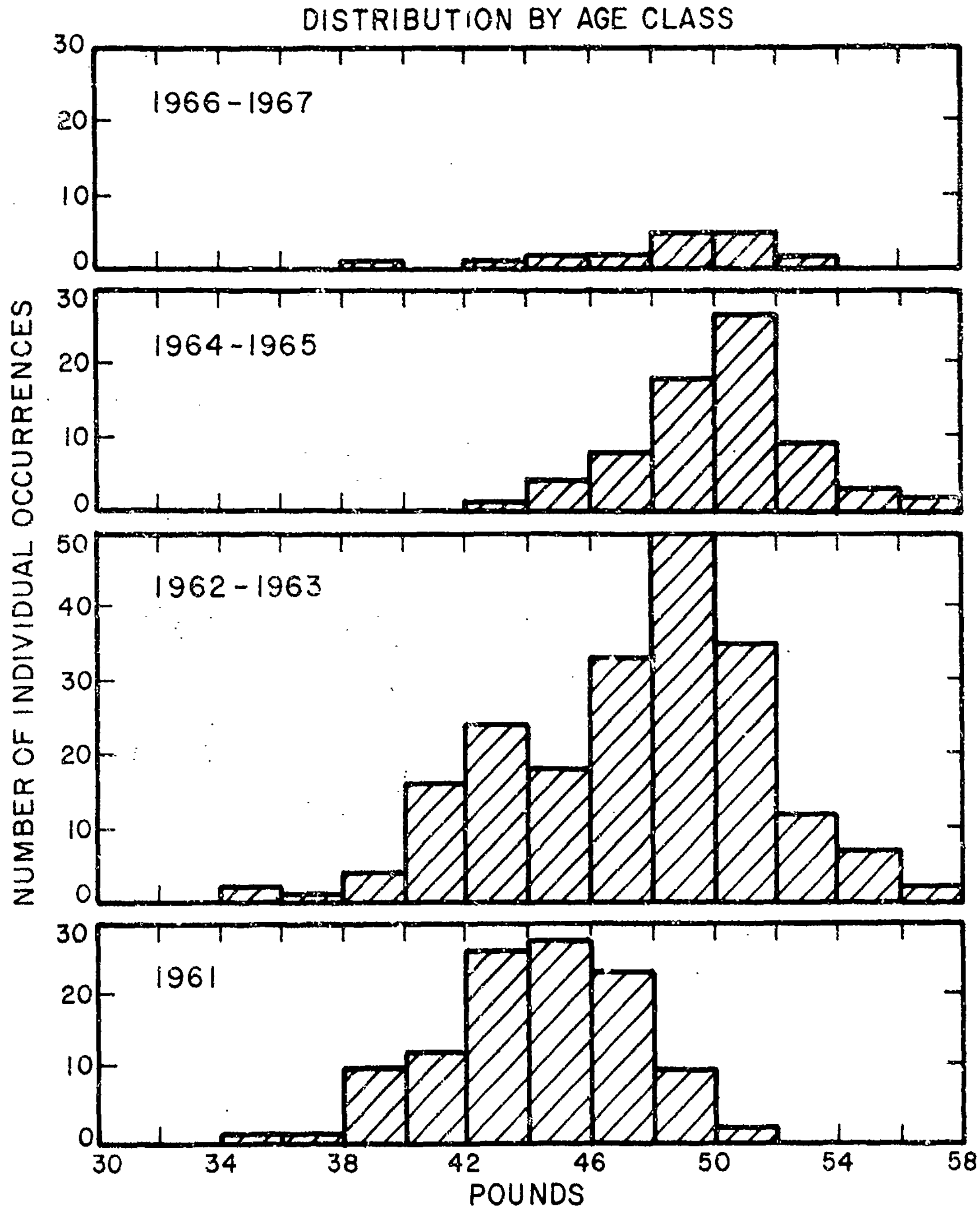


CHART 13 BREAKING STRENGTH FREQUENCY DISTRIBUTION OF CANOPY FABRIC SECTIONS FROM T-10 CHEST RESERVE PARACHUTES

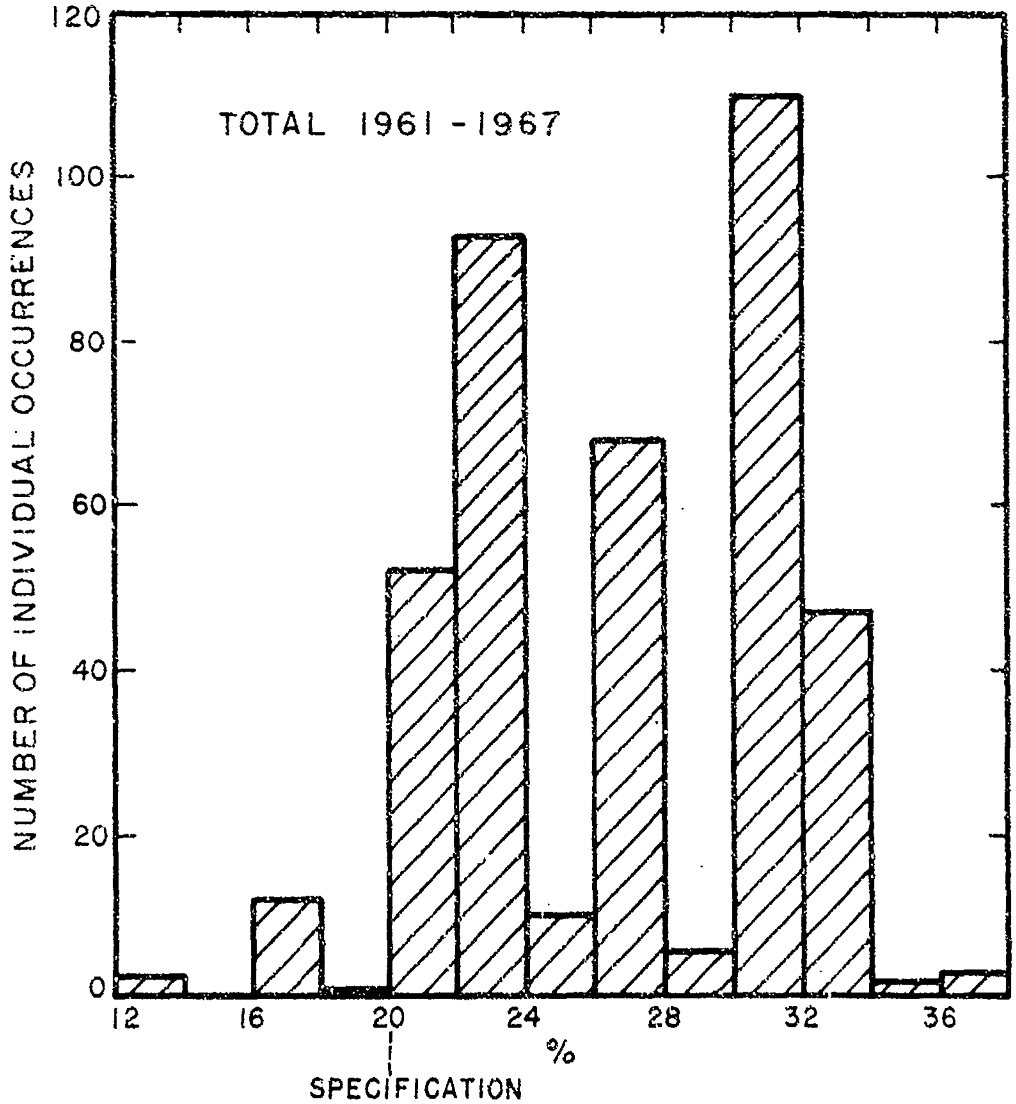


CHART 14 ELONGATION FREQUENCY DISTRIBUTION OF CANOPY FABRIC SECTIONS FROM T-10 CHEST RESERVE PARACHUTES

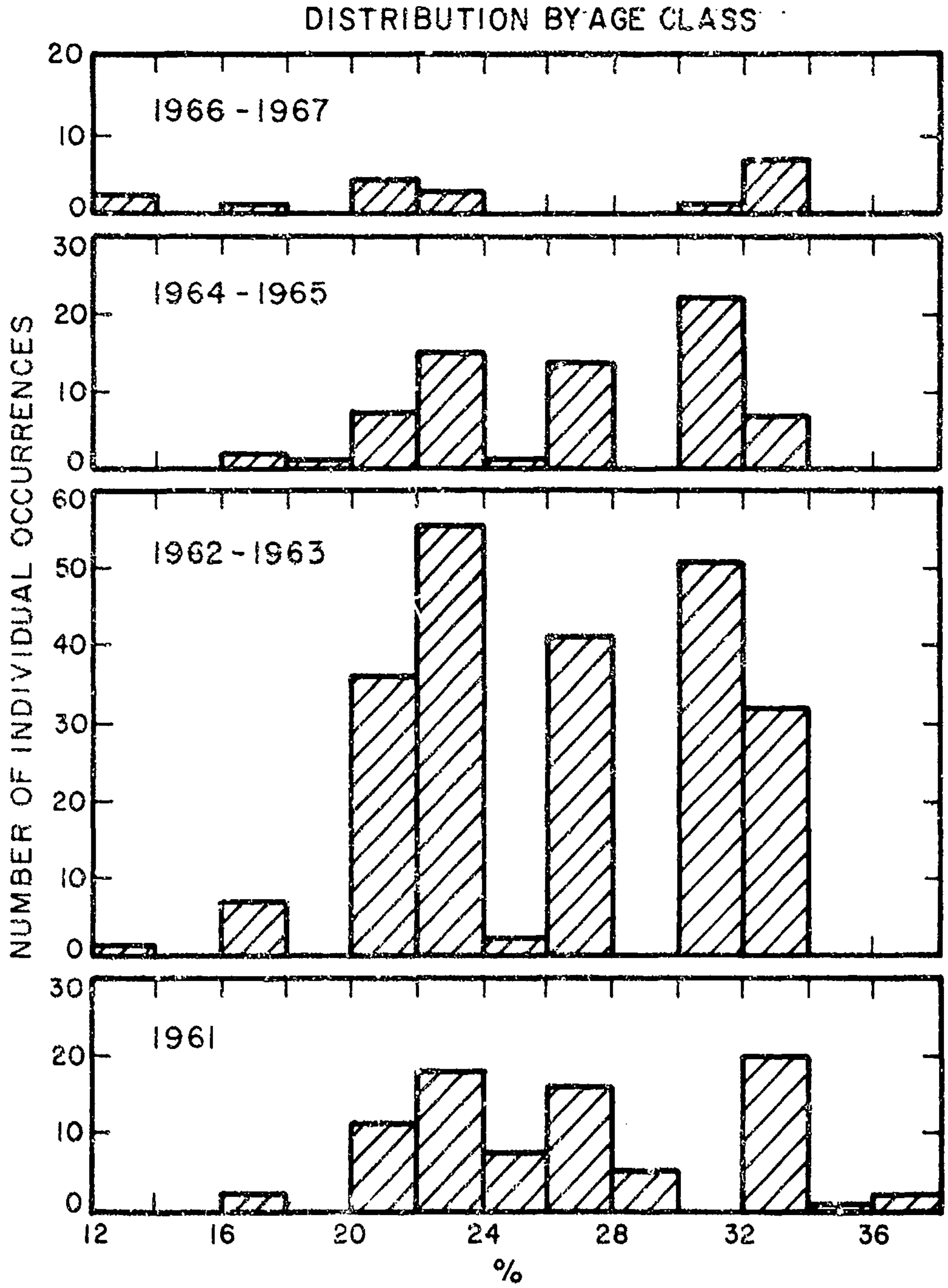


CHART 15 ELONGATION FREQUENCY DISTRIBUTION OF CANOPY FABRIC SECTIONS FROM T-10 CHEST RESERVE PARACHUTES

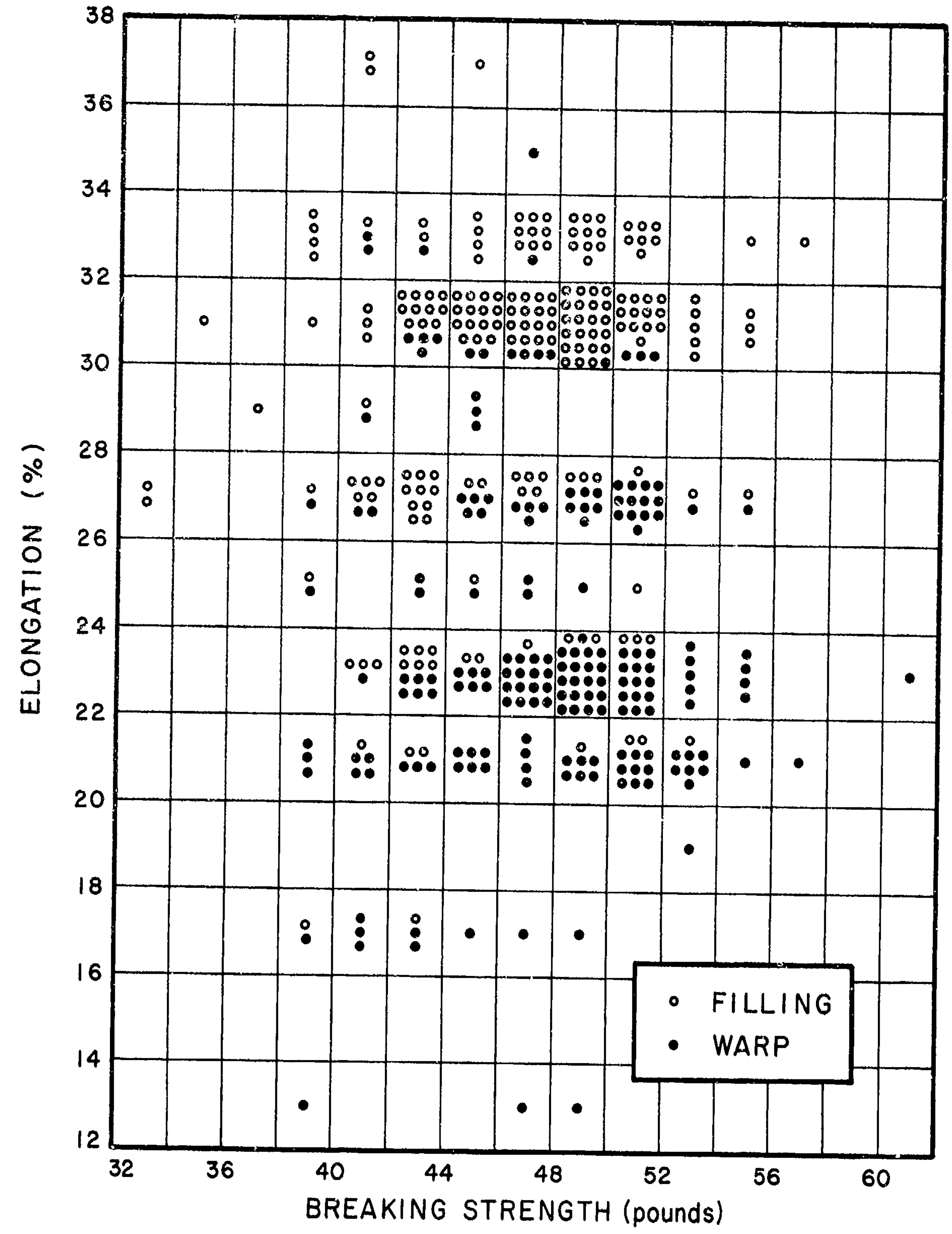


CHART 16 BREAKING STRENGTH—ELONGATION RELATIONSHIP OF CANOPY CLOTH FROM T-10 CHEST RESERVE PARACHUTES

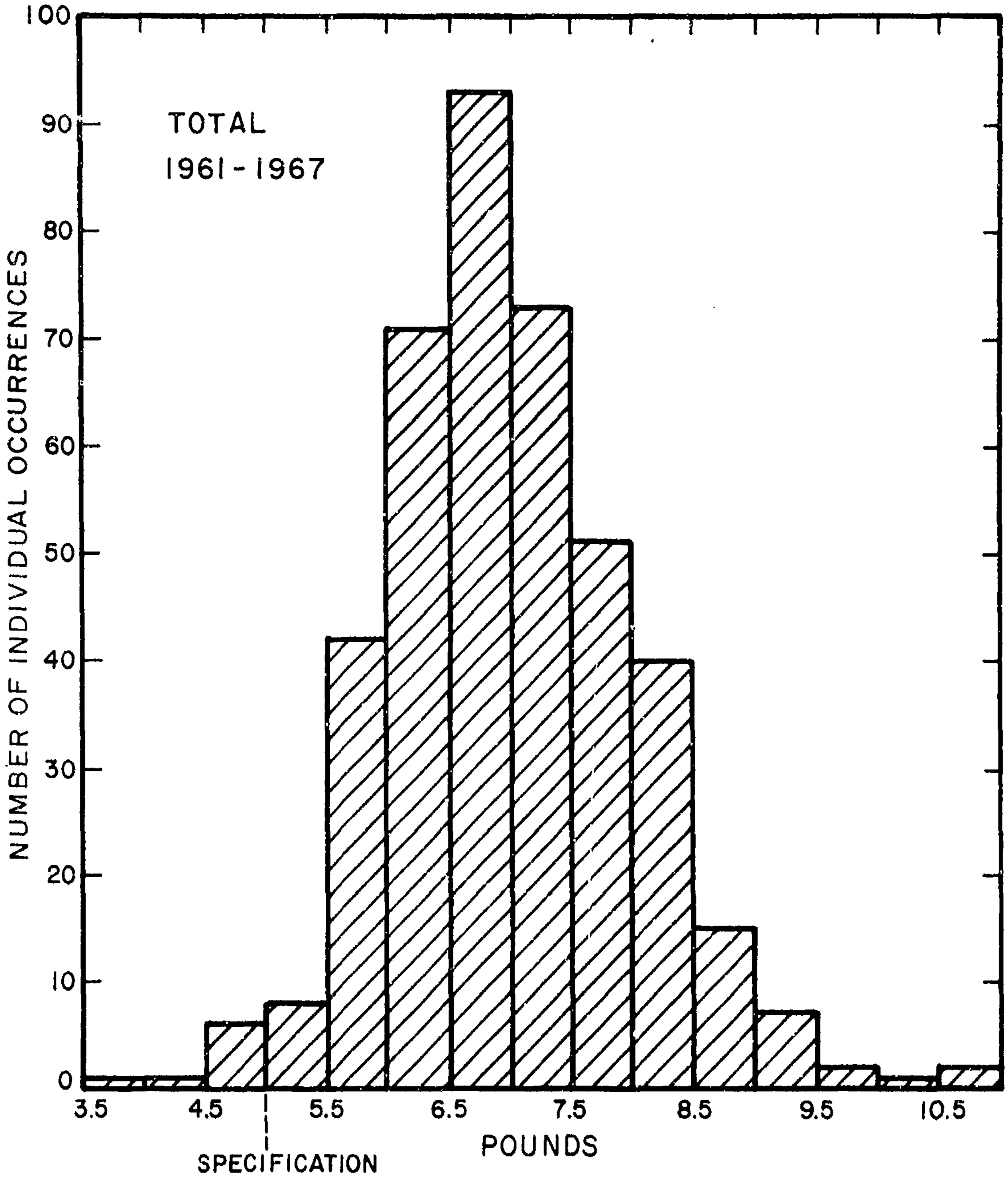


CHART 17 TEAR STRENGTH FREQUENCY DISTRIBUTION OF CANOPY FABRIC SECTIONS FROM T-10 CHEST RESERVE PARACHUTES

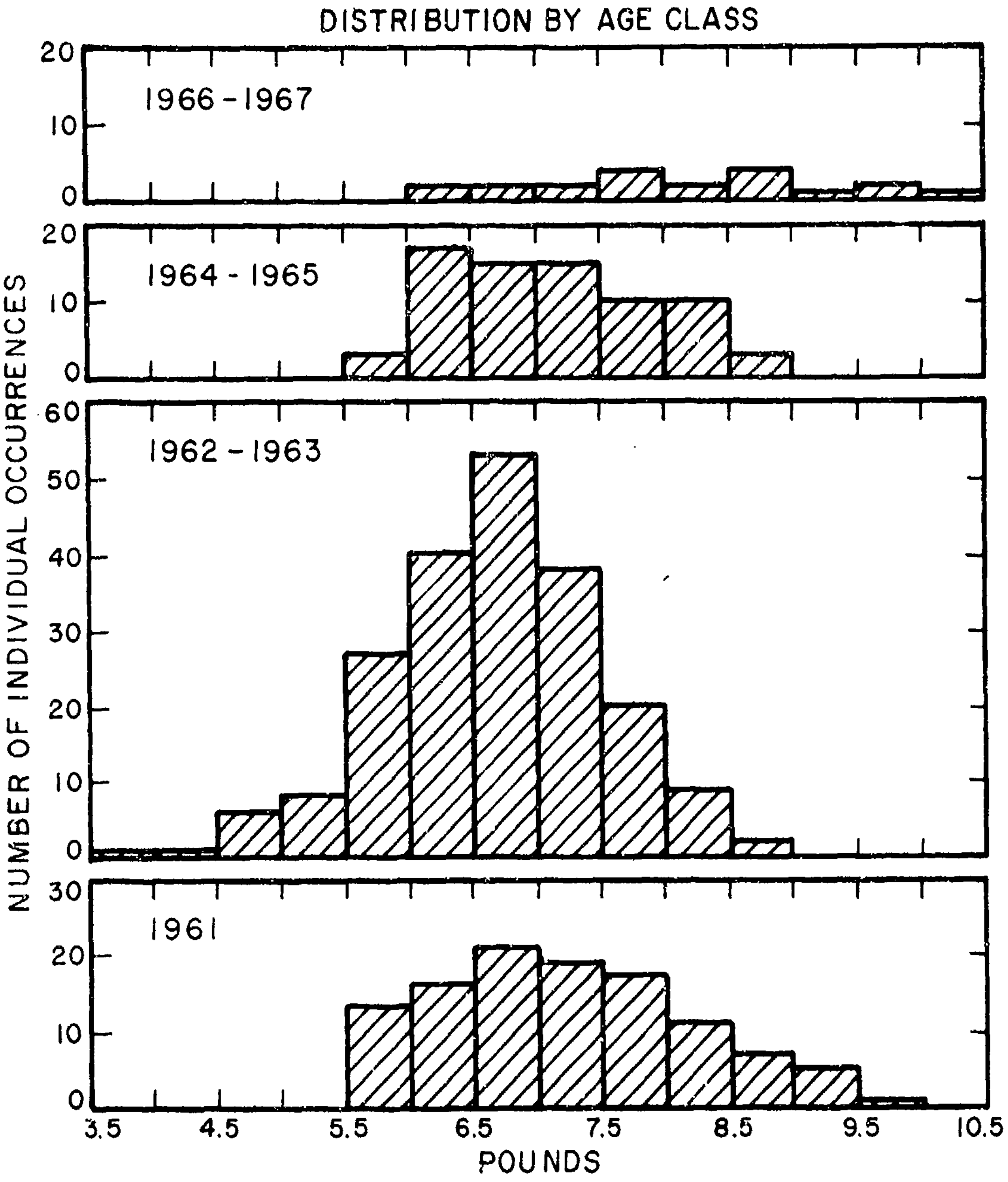


CHART 18 TEAR STRENGTH FREQUENCY DISTRIBUTION OF CANOPY FABRIC SECTIONS FROM T-10 CHEST RESERVE PARACHUTES

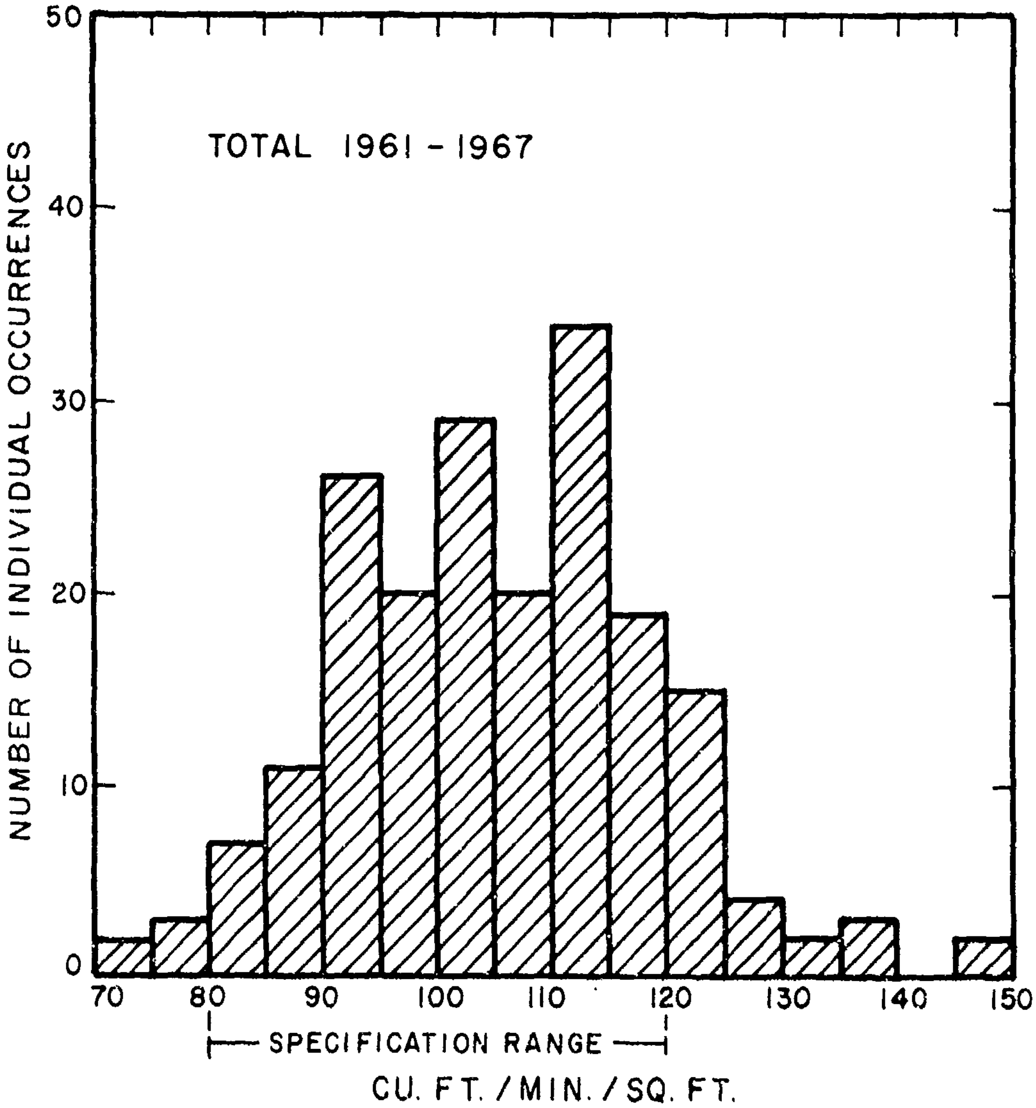


CHART 19 AIR PERMEABILITY FREQUENCY DISTRIBUTION OF CANOPY FABRIC SECTIONS FROM T-10 CHEST RESERVE PARACHUTES

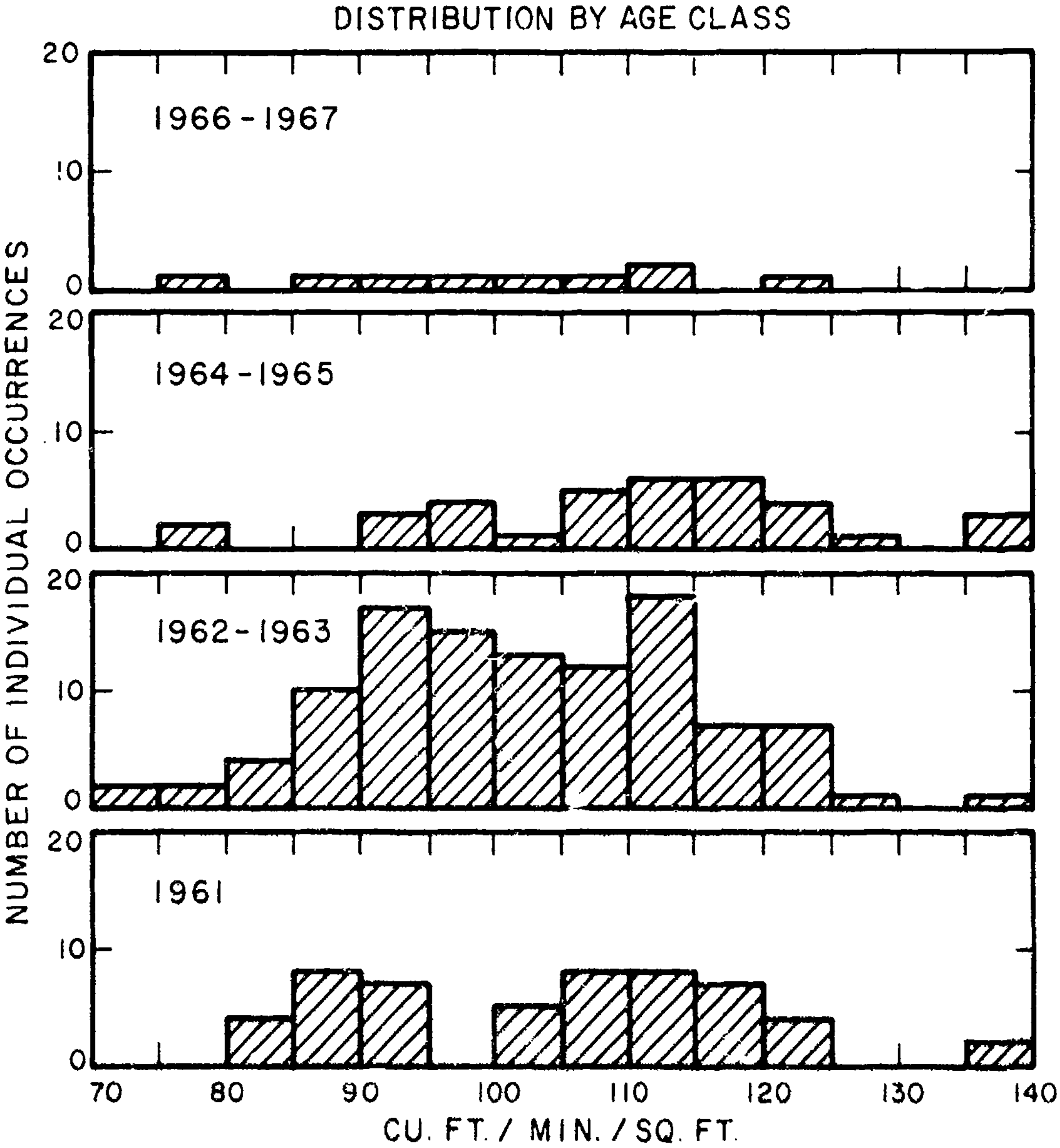


CHART 20 AIR PERMEABILITY FREQUENCY DISTRIBUTION OF CANOPY FABRIC SECTIONS FROM T-10 CHEST RESERVE PARACHUTES

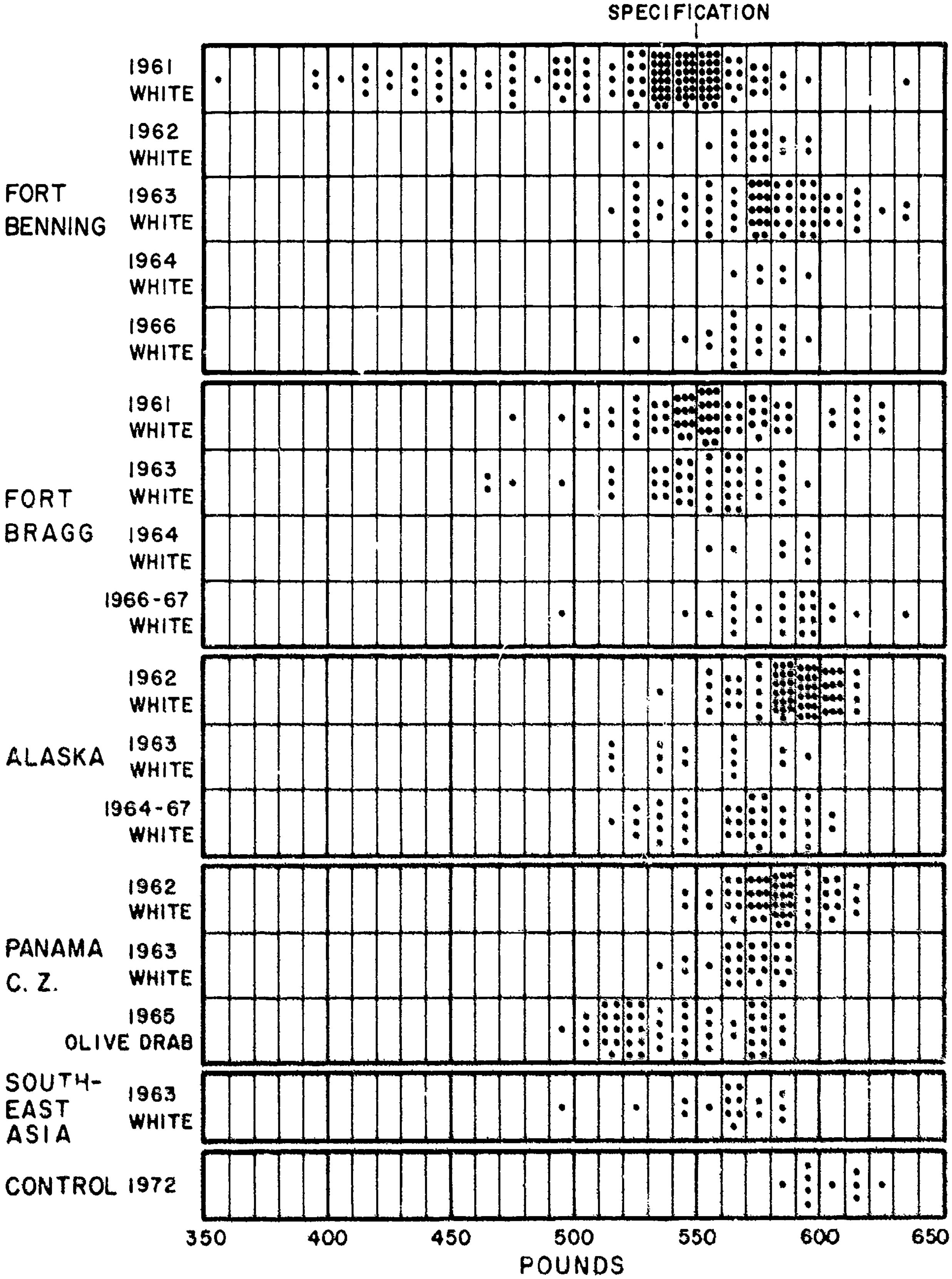


CHART 21 BREAKING STRENGTH OF SUSPENSION LINES FROM T-10 CHEST RESERVE PARACHUTES

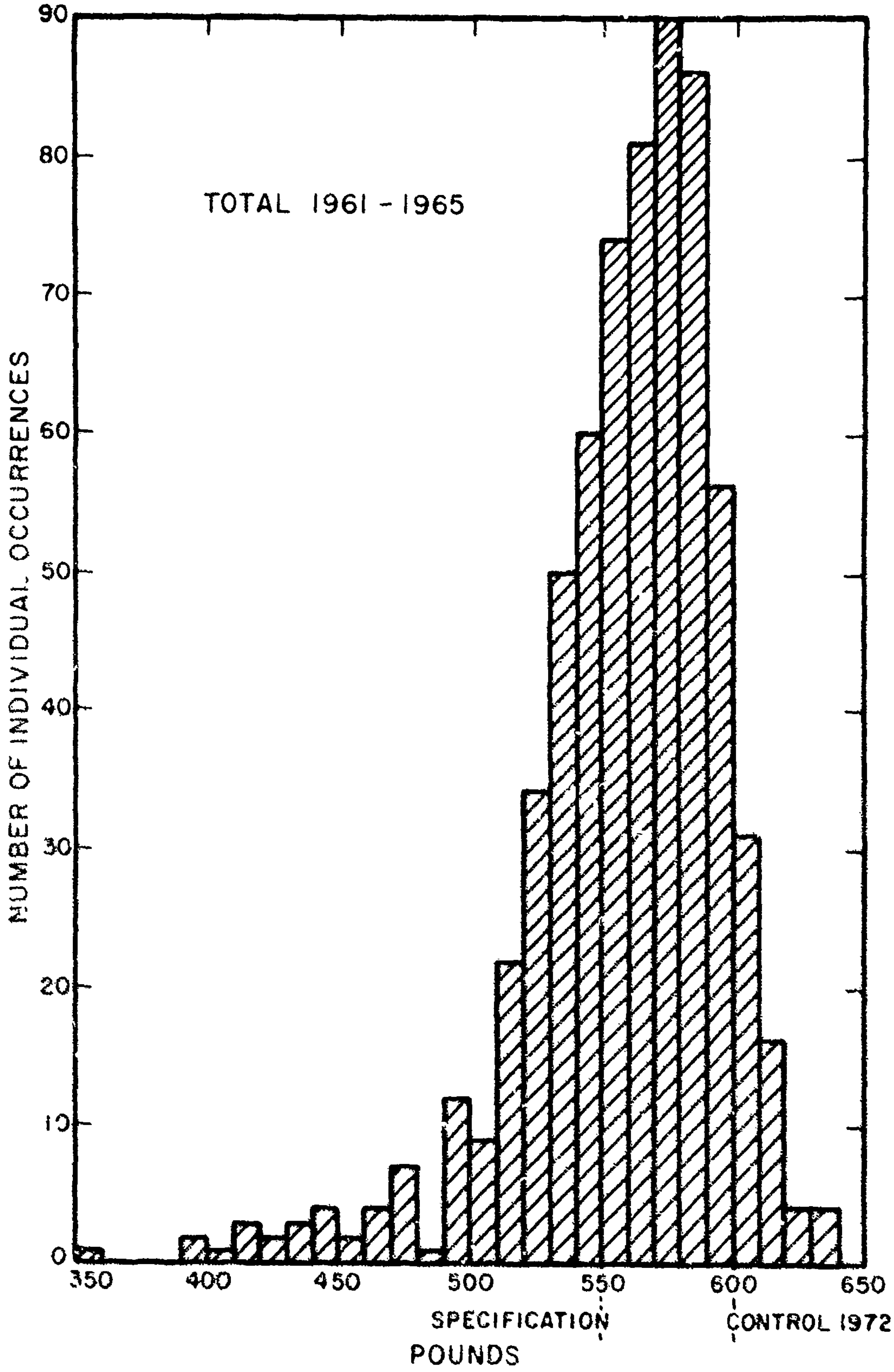


CHART 22 BREAKING STRENGTH FREQUENCY DISTRIBUTION OF SUSPENSION LINES FROM T-10 CHEST RESERVE PARACHUTES

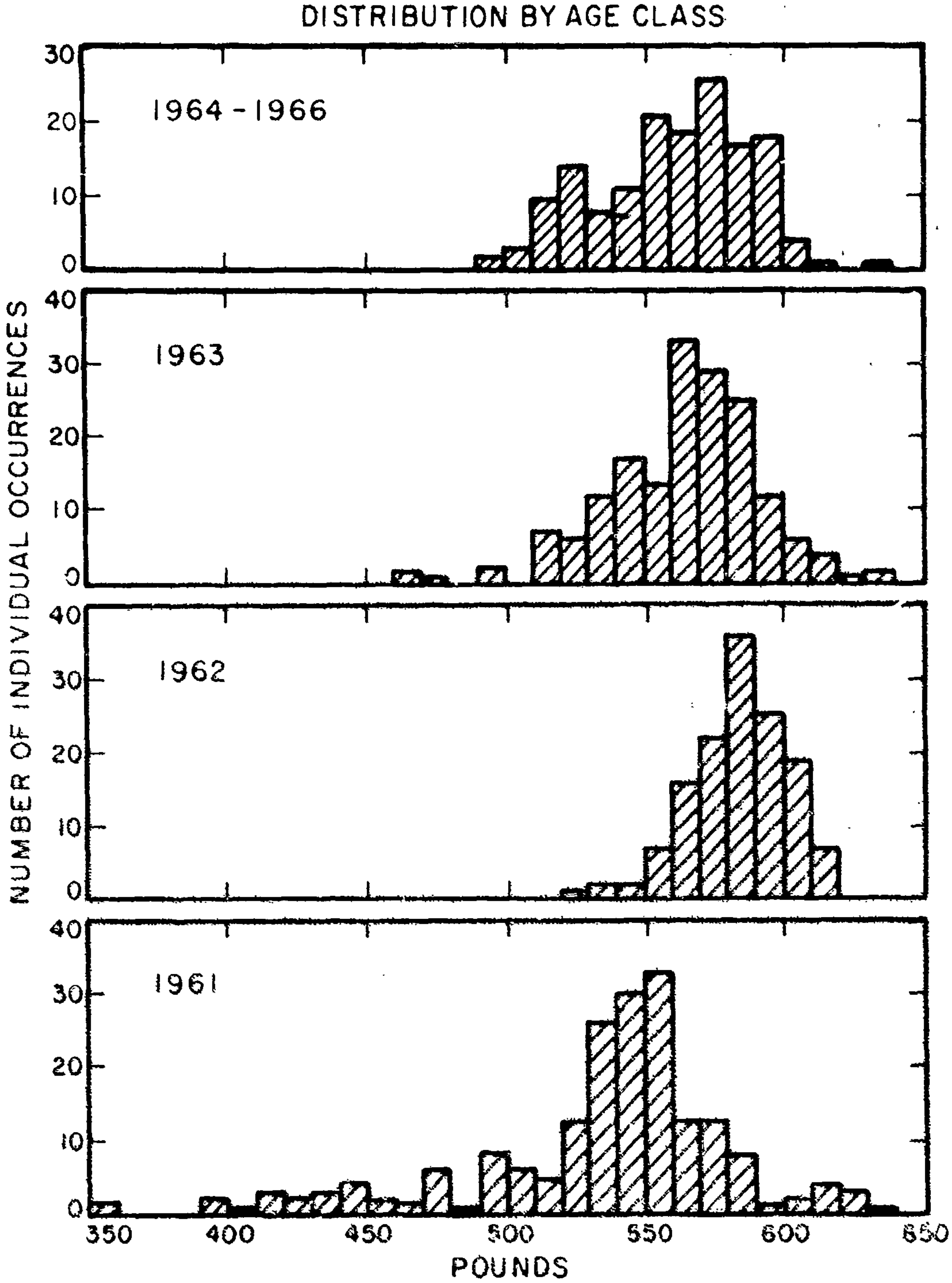


CHART 23 BREAKING STRENGTH FREQUENCY DISTRIBUTION OF SUSPENSION LINES FROM T-10 CHEST RESERVE PARACHUTES

	Opening Force 7,100 Ft (lb)	(g)	Opening Time 7,100 Ft (sec)	Rate of Descent 6,000 Ft (ft/sec)	Rate of Descent 464 Ft (ft/sec)
			T-10 Main Parachute		
Maximum	2189.6	8.1	4.4	22.6	24.4
Minimum	1436.5	5.3	3.6	19.0	17.4
Average	1574.1	5.8	4.1	20.9	20.3
Range	753.1	2.8	0.8	3.6	7.0

	Opening Force 11,100 Ft (lb)	(g)	Opening Time 11,100 Ft (sec)	Rate of Descent 10,000 Ft (ft/sec)	Rate of Descent 464 Ft (ft/sec)
Maximum	2342.8	8.7	4.8	25.4	22.4
Minimum	1238.5	4.6	2.8	20.4	14.9
Average	1578.9	5.8	4.1	21.6	18.8
Range	1104.3	4.1	2.0	5.0	7.5

T-10 Reserve Parachute

	Opening Force 7,100 Ft (lb)	(g)	Opening Time 7,100 Ft (sec)	Rate of Descent 6,000 Ft (ft/sec)	Rate of Descent 464 Ft (ft/sec)
Maximum	3773.3	14.0	5.6	39.2	40.1
Minimum	1676.3	6.2	3.6	17.4	18.7
Average	2630.0	9.7	4.5	28.9	27.3
Range	2097.3	7.8	2.0	21.8	21.4

	Opening Force 11,100 Ft (lb)	(g)	Opening Time 11,100 Ft (sec)	Rate of Descent 10,000 Ft (ft/sec)	Rate of Descent 464 Ft (ft/sec)
Maximum	4162.9	15.4	8.4	32.0	27.8
Minimum	2392.4	8.9	3.6	23.7	20.7
Average	3507.0	13.0	5.7	28.9	24.5
Range	1770.5	5.5	4.8	8.3	7.1

CHART 24 RDTE Project No. 1F162203D19517, USATECOM Project No. 8-EG065-000-002/003, Engineering and Service Test of Standard Air Delivery Equipment (Personnel and Cargo at High Drop Zone Elevations)

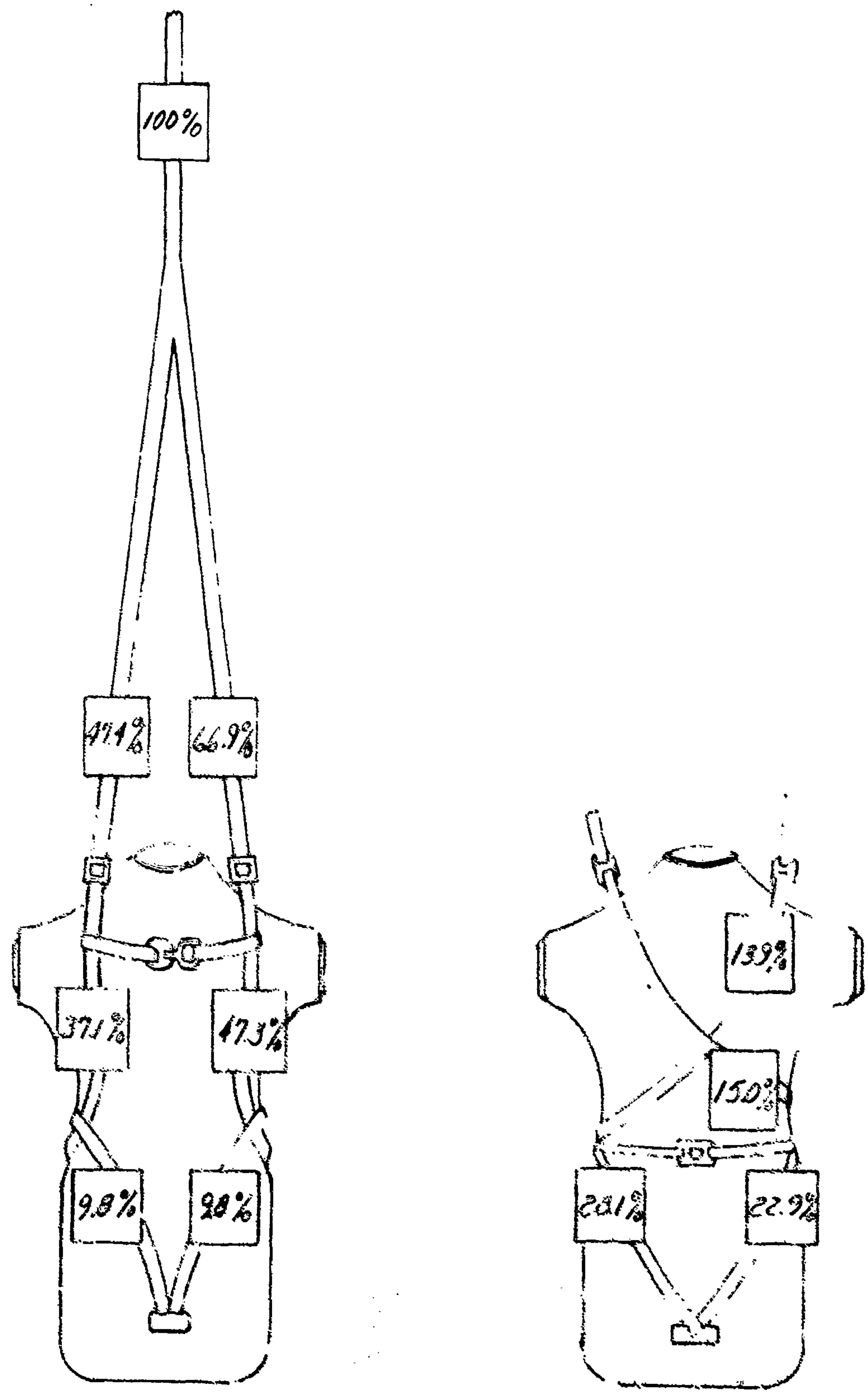


CHART 25 Maximum Force Percentages Measured on a Parachute Harness During Canopy Opening